

ARCTIC

Journal of the Arctic Institute of North America

Vol. 8, No. 2

Published in Ottawa, Ontario

1955

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RECENT GLACIER ACTIVITY IN THE TAKU INLET AREA, SOUTHEASTERN ALASKA

Alfred Philip Muntz

RECENT studies have shown that in the middle of the eighteenth century the Norris and Taku glaciers, together with others issuing from the Juneau Ice Field, had advanced considerably beyond their present positions, and were, presumably, even farther beyond the positions of the termini during the thermal maximum (Lawrence, 1950a). A similar pattern of advance and retreat has been noted for certain glaciers elsewhere in Alaska and in many other parts of the world, and the period during which the advance occurred has been termed "the little ice-age" (Matthes, 1939, p. 520). Evidence for increased glacier activity in a late postglacial maximum seems abundant and clear, but details of the fluctuations of individual glaciers are frequently lacking, although such information is essential if the causes of the glacial changes are to be understood.

This paper discusses the significant features of recent fluctuations of the lower Norris and Taku glaciers, including their maximum extent, date of important phases, and the relationship of the glaciers to other physical features of the area. The glacier variations in the Taku valley are of particular interest because observations are now being made on the regimen of these glaciers, and on the effect of changes in the regimen at higher levels on the position of the ice in the valley. The resultant information should be of value in providing a better understanding of glaciation.

Present conditions

The Juneau Ice Field occupies an area of approximately 700 square miles in the Alaskan Coast Mountains, north of Juneau and east of the Lynn Canal. From it flow a number of valley glaciers, five of which emerge on the southeastern side and reach the broad trench of the Taku Inlet and River. These are the Norris, Taku, Hole-in-the-Wall, Twin, and Tulsequah glaciers. Except for the Taku and its distributary, Hole-in-the-Wall, all the glaciers appear to be retreating. The apparently anomalous advance of the Taku has received much attention, particularly since the organization of the Juneau Ice Field Research Project by the American Geographical Society in 1948, and some progress has been made towards an understanding of the present advance (Heusser, Schuster, and Gilkey, 1954). The Norris Glacier, which terminates less than a mile from the Taku and emanates from the same group of interconnected névés, appears to be retreating and is thinning rapidly.



Fig. 1. View northwest along Norris Glacier. 1942.

Photo: U.S.A.F.

Past conditions

Different methods may be used to determine the condition of glaciers in the past, and to date major advances and recessions. Historical records may provide information, but unfortunately early detailed descriptions of glaciers are rare. Geological evidence is invaluable in most respects, but does not

generally permit accurate dating of events. Radiocarbon dating of organic material less than 500 years old is not sufficiently accurate for meaningful results. Botanical studies, particularly pollen and tree ring analysis, have been of great significance and recently geobotany, the union of geological and botanical approaches, has provided a fairly reliable means of dating recent events.

Very little of the information thus far compiled concerning the recent maximum of the Norris and Taku glaciers has been based on historical records. Written descriptions of these glaciers before the 1800's are unknown, although the glaciers of Taku Inlet in general are mentioned by Vancouver (1801, p. 25-7) who charted the area in 1794. He describes a basin, about 13 miles within the inlet, and Lawrence (1950a, p. 208) cites a reference by Vancouver in which he suggests that "the Norris still had a vertical tidal icefront in 1794". The reliability of Vancouver's description is doubtful, and it is impossible to base final conclusions on the scanty data he gives. There is, at present, no basin visible; however, if his description of the Taku Inlet is compared with maps made around 1900, a strong correlation exists. At that time the terminus of the Taku Glacier was more than 3 miles farther up its valley than at present, and this exposed part of the inlet was approximately the same as the basin Vancouver described more than 100 years earlier. In 1890 I. C. Russell visited the Taku Glacier and reported that it was retreating. Since the beginning of the present century the glacier has been advancing rapidly, and in 1949 Lawrence (1950a, p. 209) estimated that it had advanced $3\frac{1}{2}$ miles in 48 years.

The Norris Glacier has had a somewhat different history during the present century. Since about 1915 it has been retreating, and although the recession of the ice itself has not been great, the amount of thinning that has occurred near the terminus is considerable. Before 1915 the ice stood at a high level for at least several decades, for early photographs show that in the 1880's the ice was "close to or in contact with the trees along the margins" (Lawrence, 1950a, p. 208). Evidence obtained by the writer indicates that this high level was maintained for a very long period.

Although a period of increased glacier activity in the recent past has been recognised, it was not until 1949 that any significant attempt was made to determine the extent to which the glaciers in the vicinity of Juneau and the Taku Inlet had been affected. During July and August 1949, Lawrence studied the termini of several glaciers of the Juneau Ice Field, and the data he obtained are of great value, especially as they demonstrate the effectiveness of the geobotanical approach to the study of recent glaciation. By comparing the annual growth rings of trees on both sides of the line of recent maximum advance Lawrence was able to estimate not only the approximate date at which the ice began to retreat from its maximum position, but also the minimum length of time that had elapsed since the ice last advanced beyond that position. He concluded that all the glaciers studied had advanced to a maximum that culminated during the early or middle eighteenth century, and that retreat began around 1765 (Lawrence, 1950a). The writer carried out detailed

investigations in the Taku Inlet area in 1953 in an attempt to determine the extent of the late postglacial maximum of the Taku and Norris glaciers in terms of farthest advance and greatest thickness at or near the termini, and to date the maximum as closely as possible. The conclusions, in part, support those of Lawrence, although evidence for a mid-eighteenth century maximum was not found on the lower Norris, but the writer has interpreted certain other phenomena associated with recent glaciation in this area differently.

Research methods

The methods employed were essentially those used and described by Lawrence (1950b). The forest trimlines of the Norris and Taku glaciers were studied carefully both on air photographs and in the field. Trimlines are formed by a glacier advancing down a forested valley and destroying all the trees in its path, creating a sharp line between the forest untouched by ice and that sheared off. Trimlines are frequently associated with lateral or terminal moraines, but whereas trimlines are invariably formed by a glacier advancing through forests, various factors may prevent the formation and survival of moraines. When the glacier retreats or thins, the trimline is left above and beyond the existing ice. Normally reforestation soon begins on the area cleared and abandoned by the ice, but the time required for seedlings to become established on freshly deglaciated terrain varies with local conditions. Lawrence determined that 3 to 7 years were necessary for Sitka spruce to become established on land from which the Mendenhall Glacier has recently retreated (1950a, p. 202) and it is reasonable to assume that a similar period is required in the Taku-Norris area. The number of years necessary for the re-establishment of seedlings plus the age of the oldest trees below or inside a trimline, indicates the number of years that an area has been deglaciated. From an examination of forest conditions and an analysis of sections and cores from trees growing on the outer side of a trimline, it is possible to estimate the time that has elapsed since ice last advanced over the area. Differences between forest conditions on either side of a trimline gradually become less marked and may eventually be obscured, but they can still be observed after more than 200 years.

In this study, trimlines were recognized and traced on the basis of both geological and botanical evidence, and cores or sections were taken from trees which were believed to be of a significant age. Equipment used included Swedish increment borers, capable of extracting a core of 15 to 20 inches, and a small hand saw for obtaining sections from small trees.

In order to make a reliable estimate of the age of a tree, the total number of annual growth rings must be counted, and the core must, therefore, be taken from the exact centre and the very base of the tree. This was frequently impossible, and in such cases it was decided to add one year for each foot of height between the base of the tree and the point of extraction. If the centre of the tree could not be reached with the coring device, the number of rings remaining was estimated by multiplying the number of rings in the most central inch of the core by the number of additional inches required

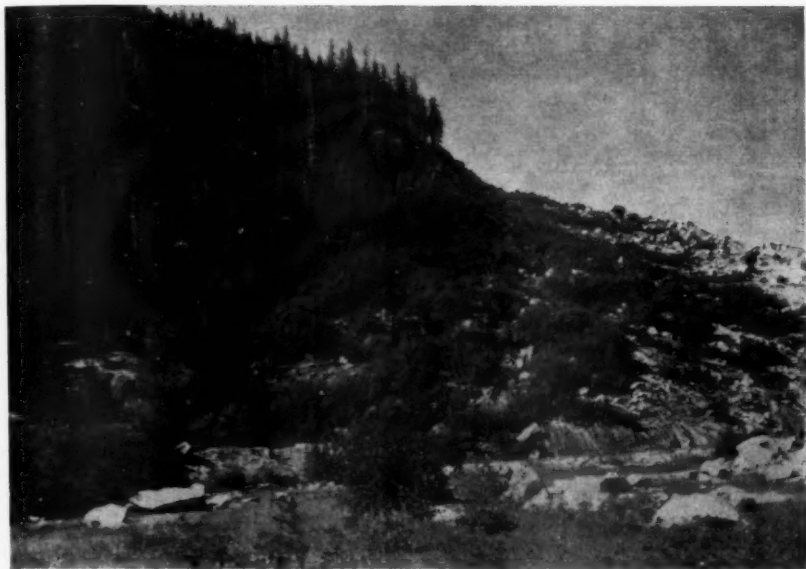


Fig. 2. Trimline of Norris Glacier, on slopes above southern end of the present terminus. Narrow belt of spruces adjacent to trim follows lateral moraine. August 1953.

to reach the centre. For example, if a 14 inch core containing 100 rings was extracted 3 feet above the base of a tree 36 inches in diameter at the point of extraction, and if the innermost inch of the core contained 4 rings, then the age of the tree was estimated at 119 years—the additional 19 years being the sum of the height in feet of the core above the base (3) and the product of the number of rings in the innermost inch (4) by the number of additional inches required to reach the centre of the tree (4). In the following discussion the exact number of rings counted is given, and the computed addition is in parentheses when necessary.

Norris Glacier

Casual observation shows that the lower Norris Glacier formerly filled the valley it occupies to a much greater extent. The rocky walls which confine the ice and tower above it show with remarkable clarity the recent fluctuations in height of the ice. Less obvious, but nevertheless apparent, are the indications of the time which has elapsed since the higher levels were abandoned by the shrinking glacier. Clearly defined zones of vegetation, in different stages of development, are the most easily seen indices of the age of the various levels, although they are frequently complicated by factors other than those directly associated with the ice. The vegetation zones range from bare rock and rock flour containing occasional masses of ice immediately

above the present surface of the glacier, to an ancient forest high on the upper slopes, and where slope conditions permit, the progression from tiny pioneer plants to large alders and spruces is readily observable (Fig. 2).

Conditions on both the south and north walls of the lower Norris gorge are similar, and on both, the highest level attained by the glacier in the recent past is marked by a striking trimline, accompanied, where slopes are not prohibitively steep, by a well-defined lateral moraine. The youthful forest immediately below the trimline is very different from that above, and smashed and broken stumps and trunks are still well preserved along the line of trim. These observations suggest that the ice stood at this high level recently, probably within the present century. Subsequent investigations support this idea. Cores and, in the case of small trees, sections were taken from trees on both sides of the trim on the slopes above the northern and southern sides of the glacier. The results were essentially the same. Below the trimline, the oldest tree discovered, growing on the lateral moraine 400 feet above the present ice level, was 40(2) years old. If this age plus five, to permit establishment as a seedling, is the number of years that has elapsed since the ice retreated from the trimline, the ice must have stood at the level of the trim as recently as 1906.

More accurate dating of the maximum represented by the trimline was made possible by the discovery, on the slopes overlooking the southern edge of the present glacier terminus, of a living Alaska yellow cedar, within 10 feet of the trimline, that had been pushed by the ice and/or morainic material and tilted to an angle approximately 80° from the vertical. The fact that this cedar was lying between two logs still partially embedded in the moraine precluded the possibility that some other agent could have tilted the tree. A section from this yellow cedar showed that it had been severely damaged in 1910, and that differential growth as a result of tilting began in 1920. As descriptions of the Norris mention a high ice level in the late 1800's and early 1900's, the trimline evidence merely confirms the historical record. Analysis of cores from trees growing on the outer side of the trimline, however, revealed an additional and highly significant fact—that the 1910 maximum was probably higher than any the glacier attained since approximately 1200 A.D. This is deduced from the age, 473(300) years, of a huge spruce growing within 10 feet of the tilted yellow cedar, and from the advanced ages of other spruces and hemlocks growing adjacent to the trim that were also cored.

This early twentieth century maximum of the Norris is apparently unique among the glaciers of the Juneau Ice Field which have so far been studied, although relatively minor advances at this period have been noted elsewhere. It is possible that the Norris had a mid-eighteenth century maximum and that instead of retreating rapidly the ice maintained its high level until approximately 1900, when a relatively minor advance and/or thickening formed the trimline described. Little evidence for this exists, with the possible exception of a trimline in a tributary valley occupied by "Glory Lake" (Fig. 1). The slope between the lake and the trimline, 310 feet above, is covered with shrubby willows and alders. The complete lack of tree stumps or trunks shows that no



Photo: W. O. Field

Fig. 3. "Glory Lake" 1926. View southwest from point above the lake outlet, close to Norris Glacier.



Fig. 4. "Glory Lake" 1953. Trimline above the western shore is less clearly defined and shrubs are growing on moraine in foreground.

forest has existed here for hundreds of years. A possible explanation is that the lake was dammed by the ice of the Norris Glacier when it advanced into the mouth of the tributary valley during the 1910 maximum. It is, however, impossible to be sure that the 1910 ice dammed the lake to the height of the apparent trimline as a wall of ice could have entered the valley mouth without raising the level of the lake. A photograph of the outlet of "Glory Lake" by William O. Field proves that the lake was not ice-dammed in 1926 and the treeless zone above the western shore of the lake was even more clearly defined than at present (Figs. 3 and 4); this suggests that the lake covered the treeless area only a few years before this photograph was taken.

If one accepts this theory of an ice-dam raising the level of the lake to the height of the apparent trimline, the complete absence of water-killed forest must still be accounted for. One answer is that the ice-dam persisted long enough to complete the destruction of the drowned forest. It seems unlikely that the trimline was formed by Norris ice advancing far up the valley, since the trim of the 1910 maximum is accompanied by a lateral moraine which can be traced into the mouth of the tributary valley, crossing it within a few feet of the northern extremity of the lake.

The alternative, that the absence of forest and forest remnants from the treeless zone is due to a high lake level maintained by an ice-dam for a very long period supports the theory that the Norris Glacier stood at or near the line of the 1910 trim for a great length of time. If valid, this introduces many problems, among which is the question of why the Norris Glacier was not affected by a major recession in the nineteenth century. Further investigations of "Glory Lake" and its trimlines may contribute significant information on the recent behaviour of the Norris.

Since the location of the termini of the Taku Valley glaciers at different periods has been a matter of considerable speculation, an attempt was made to determine the position of the Norris terminus during the recent maximum. The lateral moraines which accompany the trimline of the 1910 maximum were traced down to the well-defined terminal moraine a short distance beyond the present terminus. They show that although the ice then stood more than 400 feet higher less than a mile from the present ice front, the terminus was only $\frac{1}{4}$ to $\frac{1}{2}$ mile farther advanced than today. The abrupt descent of the lateral moraine indicates that the gradient of the ice surface near the terminus, during the maximum, must have been steep.

Taku Glacier

The lower Taku was not investigated as thoroughly as the Norris, although several important details concerning its recent maximum were established. Particularly significant was the determination of the height of the maximum near the present terminus, and confirmation that the maximum occurred in the mid-1700's.

Forest conditions above the lower Taku ice contrast strongly with those adjacent to the Norris. Instead of recently deglaciated terrain, with vegetation ranging from a few pioneer species upwards to substantial but never-

theless youthful trees, the southeastern slopes of lower Norris Ridge are mainly covered by a forest of trees so big that cursory examination alone suggests they are very old. Actually this is a first generation forest, in spite of the great size of the trees (Lawrence, 1950a, p. 209).

In a preliminary reconnaissance, the writer observed an old lateral moraine more than 500 feet above the Taku terminus with similar large trees on and below it. Subsequent measurements revealed that the forest below the moraine was also first generation and that none of the trees exceeded 250 years in age in spite of their massive girth. The moraine was, therefore, formed during the recent maximum of the Taku.

The lateral moraine is for the most part prominent and well-defined, and so large that the ice must have remained at that height for a great length of time (Fig. 5). The moraine can be traced for a considerable distance, but on the slopes above the present terminus of the Norris it becomes inconspicuous and can no longer be recognized, and attempts to trace it as far as the 1910 trimline of the Norris failed. Why the moraine disappears at this point is not known, although the increasing steepness of the slope may be one cause.

The moraine descends slowly towards sea level; for the distance it was followed it declined at roughly 100 feet per mile. At its southernmost extremity, where it was last recognized, it is approximately 400 feet above the outwash plain of the Norris. If the line of the moraine is projected farther south, allowing for a decrease in elevation at the observed rate, it should reappear at an altitude of approximately 275 feet on the slopes above the Norris outwash, south of the Norris terminus. Careful investigation of this area disclosed no moraine at or near this elevation, nor was there any trace of a trimline, although cores from the largest trees growing on the lower slopes indicated they were less than 200 years old.

The age of these trees, however, cannot be considered conclusive evidence that the Taku reached these slopes during its maximum, nor can a uniform descent of the line of the moraine be assumed. In fact, conditions on the Norris, where lateral moraines descend abruptly and precipitously near the terminus, suggest that the opposite might have been true, and that the gradient of the swollen mid-eighteenth century Taku near its terminus might have been extremely steep. It is, therefore, possible that although the ice of the Taku stood more than 500 feet above the present terminus approximately two centuries ago, the glacier might have been only slightly farther advanced than it is today. This is contrary to the opinion expressed by Lawrence (1950a, p. 209).

The eastern shore of Taku Inlet was visited both above and below Taku Point to collect additional information and to examine the evidence cited by Lawrence for a mid-eighteenth century advance to Taku Point. This evidence consisted of "two fragments of what appear to be moraine ridges south of Taku Point, a forest trimline that stands 100 to 150 feet above tidewater on Taku Point, against which Norris Glacier must have pushed, and a heavily scoured region between that trimline and the inlet, over which the Taku River must have flowed when the tip of the ice dam rested there" (Lawrence, 1950a, p. 208).



Photo: U.S.N.

Fig. 5. Norris and Taku termini, Taku Inlet. 14 August 1948.

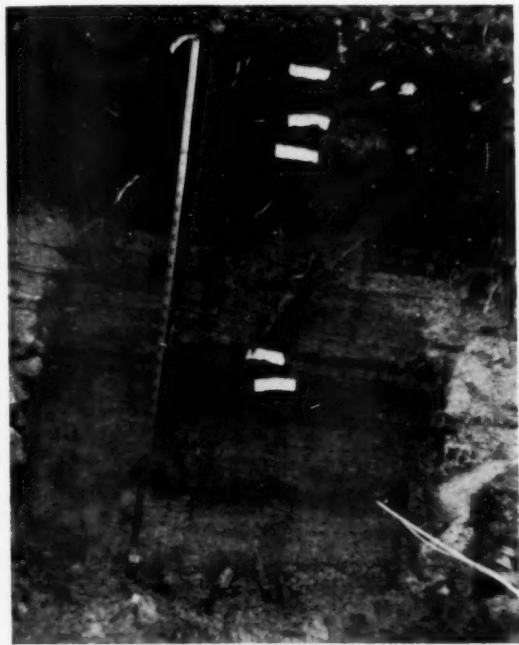


Fig. 6. Fresh profile in alluvium on east shore of Taku Inlet, south of Taku Point. Layers of organic material are indicated, and rule is extended approximately 3 feet.

The two forested areas south of Taku Point—the apparent moraine fragments mentioned by Lawrence—were found to be alluvial or marine deposits apparently laid down when sea level was considerably higher than at present (Fig. 5). The material is well stratified, with the individual layers ranging from extremely fine sand to coarse gravel. Five distinct strata containing much organic material also occur within 2 feet of the surface (Fig. 6). The deposits are covered by a youthful forest in which most of the trees are less than 100 years old, and the oldest cored contained only 104 annual rings.

These forested flats south of Taku Point are remarkably similar, in both stratigraphy and topography, to the much more extensive level area on the eastern shore of the inlet south of Taku Lodge (Fig. 5), where currents and storm waves are actively cutting back the shoreline. There are many excellent exposures showing clearly defined strata of sand and gravel of varying coarseness, with individual pebbles up to 2 inches in diameter. The area is not as level as a view from the air or from the inlet suggests; very low ridges and winding depressions are numerous, particularly in the southern portion of the plain. The surface is generally sandy, in some places so much so that tree growth is prohibited or severely limited. A dense but youthful forest covers most of the northern part and counts of growth rings on cut stumps indicate that most of the trees are less than 100 years old; the largest tree observed contained only 115(30) rings. The trees on the flats both north and south of Taku Point are, therefore, similar in age.

According to Lawrence, a lake, formed when a dam of glacial ice blocked the inlet at Taku Point, covered the flats south of Taku Lodge near the middle of the eighteenth century (1950a, pp. 209-11). No evidence for such a lake was found, and the lack of identifiable lake silts or clays in or above the deposits described, and the irregular topographic features, indicates flood plain deposition.

The similarity of the deposits north and south of Taku Point suggests a common origin, and the uniformity in the age of the tree cover of each indicates that they were formed at the same time. Although the evidence is not conclusive, the deposits are apparently remnants of alluvium which formerly choked the upper part of the present inlet. As the sea level was lowered relative to the land deposition ceased and erosion has since removed most of the material.

Higher sea levels in the past might also account for the scoured appearance of the rocky slopes up to 150 feet above present sea level, which are especially conspicuous above the western shore of the inlet. Lawrence ascribes the relative barrenness of the lower slopes of Taku Point to glacial scour, but since these conditions are evident along the shores of the inlet far south of Taku Point, the writer considers that some other factor is responsible. Abundant evidence has been obtained indicating that much higher sea levels have occurred in postglacial time along the coasts of southeastern Alaska (Twenhofel, 1952, p. 523-48) and a lowering of 150 feet is by no means improbable.

It is difficult to estimate when the lower, "scoured" slopes emerged, and the alluvial deposits first stood above high tide. The age of trees on the lower slopes cannot provide significant data, since the time required for tree growth to be established after emergence is not known. A section from a stunted spruce growing in a rock chimney less than 100 feet above present high tide, showed the tree to be 222 years old; this is a minimum figure, and the actual time since emergence must be greatly in excess of this. On the alluvial flats, once the water table was sufficiently lowered, conditions would be much more favourable for a relatively rapid establishment of seedlings, and therefore, here the age of trees can be considered a more reliable index of the date of emergence. The oldest tree discovered on the alluvial flats on the eastern shore of the inlet contained 115(30) rings, which suggests that the sea covered the flats until recently—perhaps as little as 200 years ago.

All the evidence discussed so far indicates that Taku Glacier failed to reach the eastern shore of the inlet during its recent maximum, and that changes in sea levels are responsible for features formerly attributed to glaciation. This conclusion is particularly important in attempting to forecast the limit of the present advance of the Taku. The rapid advance of the glacier since 1900 suggests that it might, in a few years, reach Taku Point, a circumstance which would obviously be of considerable significance to any future developments in the Taku Valley.

In the mid-eighteenth century Taku had not reached the eastern shore of the inlet, although it then stood more than 400 feet higher on Norris Ridge

than it does at present. If the assumptions presented above concerning the location of the 1750 terminus are correct, it is probable that the ice front has already reached its maximum position, and that an enormous thickening of the entire system would be necessary before the ice could advance across the inlet.

The field work on which this paper is mainly based was carried out under the auspices of the Juneau Ice Field Research Project, directed by the American Geographical Society and sponsored by the Office of Naval Research. The author wishes to express his appreciation to these and other cooperating organizations, to the members of the 1953 J.I.R.P. party, and to Professor Kirk H. Stone, Department of Geography, University of Wisconsin. Special thanks are due to Richard Pierce, field associate of the writer, who analysed all the tree sections and cores obtained in the field.

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GLACIOLOGICAL RESEARCH IN THE CANADIAN ARCTIC†

P. D. Baird*

THE glaciers of the Canadian Arctic are amongst the least known of the northern hemisphere. From the earliest surveys, however, it was clear that they contain numerous features of exceptional interest to the glaciologist. The ice assumes many different forms including glacier caps, highland glaciers grading into vast areas of transection glaciers, valley, cirque, and piedmont forms, and finally some unique shelf ice. It is believed that all this ice has non-temperate geophysical characteristics (Ahlmann, 1948, pp. 66-7) and that, therefore, there is a wide range of types to study, intermediate between Greenland's polar inland ice, and the temperate ice of Iceland and Norway. The regimen of the glaciers in the Canadian Arctic is apparently healthier than those studied by Ahlmann around the North Atlantic.

The highland rim of northeast arctic Canada was probably the source region from which the Wisconsin Laurentide Ice sheet expanded to cover an area nearly as large as Antarctica in eastern and central North America. At the close of the Wisconsin age the ice disappeared in southern areas and the lowlands of the north, but has persisted as remnants on Baffin, Bylot, Devon, Ellesmere, and Axel Heiberg islands to the present day (Flint, 1943).

The glacierized area under consideration (Fig. 1) extends about 1,600 miles and occupies an estimated area of 50,000 square miles. Northern Labrador is omitted as only small glacierettes exist today. Ellesmere Island, completely photographed from the air, but still to be mapped in detail, has more than half the total ice for the region. It is found in four distinct areas, Grant, Grinnell, Ellesmere proper, and North Lincoln (or Sverdrup), called "quarters" here for convenience.

Glaciology is a youthful subject and it is, not surprising that the early explorers made no real glaciological studies. However, a careful perusal of their stories reveals some information, particularly on the change in extent of the ice areas. For example, M'Clintock describes the position of the front of a Bylot Island glacier, Kaparoktalik, in 1858. He says that it was 300 or 400 yards broad, 150 to 200 feet high and extended across the valley to within 300 yards of the shore, and that an Eskimo village lay between the snout and the sea (M'Clintock, 1859, p. 157). Today the glacier is still within about 300 yards of the shore.

The Nares expedition of 1875-76 (Nares, 1878), Greely seven years later (1886), Peary (1910), and Sverdrup (1904), all contribute pieces of like

†Paper delivered to the British Glaciological Society, Bedford College, London, 17 March 1955.

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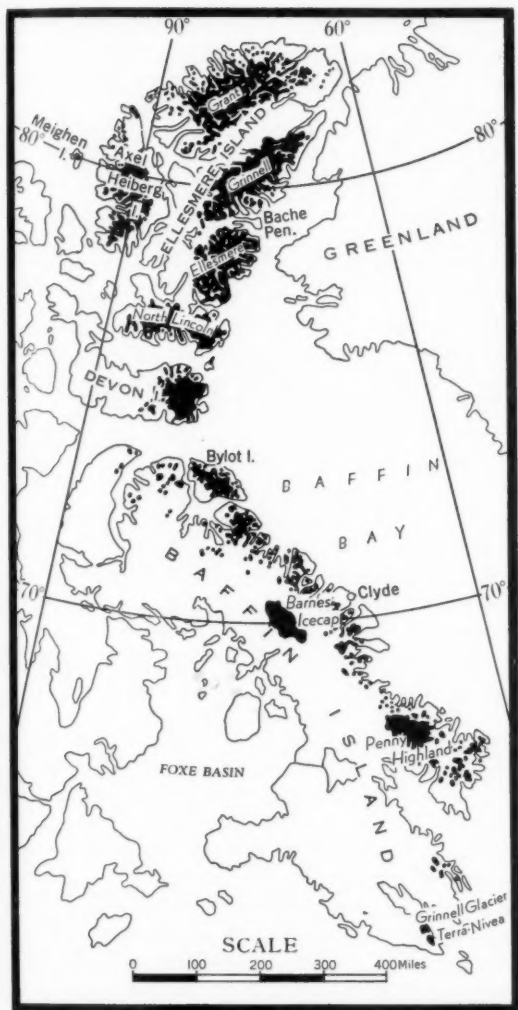


Fig. 1. Glaciers and ice caps in the Canadian eastern Arctic.

information, as do the accounts of Bernier in the early years of this century, and the Danish Fifth Thule expedition of the 1920's. A report by Eskimo to Mathiassen (Mathiassen, 1933) of this latter expedition, resulted in the first appearance of the Barnes Icecap on the map, and it was actually first viewed by members of the Wordie expedition in 1934 (Wordie, 1935, p. 311).

Prior to 1939 there were several small scale expeditions to the Canadian Arctic which, though not primarily glaciological, contributed to our knowledge of the ice regions. Wright, surveying the east coast of the Ellesmere "quarter", described the condition of highland ice, with frequent nunataks and rock ridges,

and considerable stretches of piedmont ice reaching the sea (Wright, 1940). Bentham farther south, in the North Lincoln (or Sverdrup) "quarter", was more coast-bound but he noted some interesting features: the glaciers seemed stationary or were retreating slightly; and surprisingly, he saw no erratics more than 5 miles from existing ice, and no evidence of former complete glaciation of the area at all (Bentham, 1941, p. 44). In 1932 a detachment of Royal Canadian Mounted Police found an advancing glacier had blocked the normal sledge route across Ellesmere between Bache Peninsula and Bay Fiord (*Polar Record*, 1934, p. 122).

The writer visited Bylot Island in the summer of 1939, and crossed the island by dog team in June. This is an area of transection glaciers and highland ice, previously marked as a single smooth ice cap, with many nunatak mountain peaks and ridges protruding, and piedmont glaciers extending on to the plains in the north and southwest. Moraines are weakly developed, and the glacier which I descended on the crossing to Bathurst Bay had no terminal moraine, only slight median moraine, and vegetation growing up to its front at 260 feet above sea level (Fig. 2). On June 4 at a height of 3,150 feet there was 3 feet of winter's snow on glacier ice; the firn line was obviously considerably higher on this southwest-flowing glacier than elsewhere. However, on the summit, a peak about 6,100 feet high, a small rock knob projected through a snow dome. The view from this peak shows the characteristics of interior Bylot Island (Fig. 3).

Scientists have made observations on the Grinnell Glacier in southern Baffin Island over a period of years. The majority were made by members of MacMillan's expeditions (Buerger, 1938; Roy, 1937, 1938). Their brief visits told us little, except that it was frequently foggy and that the large ice cap first described by Hall (1865, pp. 519-20) was really two small ones. Wynne-Edwards visited the area in summer 1937 and reached 2,750 feet on the ice dome in better weather than most of the other scientists (Wynne-Edwards, 1939).

Real glaciological work in the Canadian Arctic did not begin until after 1945; it has comprised the two Arctic Institute expeditions of 1950 and 1953 (Baird, 1952; Baird and others, 1953), further work on the Grinnell ice cap by Mercer¹ and the investigations of Hattersley-Smith and others on the Ellesmere Island expeditions to the north Ellesmere ice shelf in 1953 and 1954 (Hattersley-Smith and others, 1955).

In 1950 the Arctic Institute sent a strong expedition to Baffin Island to study the Clyde area, about 70°N., and the Barnes Icecap. This ice cap is quite exceptional; there can be few other ice masses of similar area, 2,300 square miles, which are surrounded by bare ground of very moderate altitude and relief and are quite unconnected with any highland source of supply (Fig. 4). The nourishment of the Barnes Icecap is also unusual; there was no developed firn, but there was (during the ablation season of 1950) an equilibrium line where the accumulation of superimposed ice on the cold surface balanced the ablation (Baird, Ward, and Orvig, 1952, p. 8). I am unable to

¹Paper to be published in *Arctic*.



Fig. 2. Bylot Island east glacier.



Fig. 3. Bylot Island, view northwest from summit, 6,100 feet.



Photo: M. H. W. Ritchie

Fig. 4. Southeast edge of Barnes Icecap.

explain the existence of this ice cap other than to suggest that it is a surviving relic from the Wisconsin ice sheet, which has persisted through the climatic optimum.

The small ice cap on Meighen Island, the farthest northwest in the Canadian Arctic, is probably similar to the Barnes in its nourishment and low ground environs, but it is probably much thinner and certainly smaller. A glaciological expedition to this island would be very interesting; it might also provide information on Krüger and Bjare who disappeared in 1930 trying to reach Meighen Island (*Polar Record*, 1934, p. 122).

In 1953 the Arctic Institute organized a second expedition to Baffin Island to examine the Penny Highland ice cap on the Cumberland Peninsula. The expedition was mainly glaciological: a station, A1, was established at 6,725 feet on the highest dome of ice, overtopped only by some slightly higher marginal mountains. This station was above the firn line which, however, was surprisingly high at 5,000 feet, although an equilibrium line was noted at about 4,600 feet. At the summit station, summer melting took place for brief periods measurable in hours only (61 the longest) (Orvig, 1954, p. 276), producing ice layers in the firn of irregular thickness and frequency. It was

*Photo: W. H. Ward*

Fig. 5. Head of Highway Glacier seen from "Concordiaplatz". Ice cap dome in the distance.

not possible to date annual layers (apart from the previous year's), but it appears that the accumulation, reduced by windsweep on the dome, is about 18 inches of water, and the temperature of the ice at depth of zero amplitude was -13°C . This was only 2°C colder than the corresponding temperature on the Barnes Icecap, although the station on the latter was nearly 4,000 feet lower. Vertical homogeneity of temperature is apparently a common feature in the Canadian Arctic, although an exception was found in Highway Glacier, an outlet glacier of the Penny Icecap, where temperatures of about -6°C were measured.

Highway Glacier, which was selected for study (Fig. 5), is connected with the main highland ice, including the dome on which the summit station was placed, but it actually draws its nourishment from a rather limited basin. From station A2 at the head of Highway Glacier at a height of 6,300 feet, down to the terminus at less than 1,300 feet, ablation and temperature stations were maintained and seismic work was carried out to determine ice thickness (Röthlisberger, 1955). At A2 refraction shooting was employed which gave wave velocities in the ice showing good agreement with those found by Holtzscherer in Greenland (Joset and Holtzscherer, 1953); they showed a

considerable accumulation of firn (about 165 feet according to the wave velocities) with an ice layer, possibly representing an abnormally warm summer, at 41 feet. The bedrock was 820 feet below the surface of the ice. At this station, situated in a col surrounded by smooth hills, accumulation was obviously greater than on the windswept dome at the summit. Later, the seismic equipment was moved down to the "Concordiaplatz", at about 3,300 feet, where three ice streams join to form the lower part of Highway Glacier; detailed reflection shooting was done here, and several sections were also made lower down.

The results show that there is no rock floor basin as one might expect at such a junction, and as is present at the Aletsch Glacier's Concordiaplatz. The sections showed regular U-shapes, with a maximum ice thickness of about 1,300 feet. This junction is undoubtedly on one of the major structural rock trends where the bedrock would likely be shattered and susceptible to the supposed erosive powers of the glaciers. All three glaciers steepen markedly above the "platz", and the ice is moving relatively quickly. At the camp site, on a lateral moraine, crevasses were groaning, and opening and closing.

A fairly reliable longitudinal profile was obtained of the lower part of the glacier; it grades very smoothly down to Pangnirtung Pass, the slope of the floor being about 1.3° and that of the surface about 3.3° . Refraction measurements were made on the thinning ice where the glacier swings east into the pass; the ice appeared to be about 500 feet thick and was underlain by supposed moraine, 90 feet thick if the material was unfrozen, or 141 feet thick if frozen (Röthlisberger, 1955, p. 546).

This area of Baffin Island has very impressive scenery, and the evolution of the landscape and the rocks on which it developed were studied by our geomorphologists and geologists. A summary of some of their findings, which pertain to the matter of this paper follows.

The old peneplain surface, now visible in the accordant summits of the mountains, was at some time in the late Tertiary, strongly uplifted, tilted, and faulted. According to Tanner (1944, p. 126) at this period in Labrador "strong tectonic movements occurred with unbounded faulting, down- and up-warping, some folding and basaltic eruption". This had also occurred in the Cumberland Peninsula. Kidd traced for 55 miles along the coast of Davis Strait, a narrow belt of basaltic flows now situated at 1,000 to over 3,000 feet above sea level (Baird and others, 1953, p. 241). Underneath were beds of agglomerate and tuff which he believes were formed beneath the sea. This indicates an uplift here of at least 1,000 feet. The uplift was much greater in the centre of the peninsula (Fig. 6) and although no very great faults were seen, Kidd observes that these granitic-type, Precambrian rocks appear to fail when under great stress in the "dry" state rather than flow plastically.

The writer agrees with Thompson (1954) that a great deal of block faulting occurred as the plateau heaved up and in the resulting rifts and crush zones local rivers began rapidly to erode valleys. The ice caps which formed on the high plateau remnants during the Pleistocene gave some protec-

*Photo: W. H. Ward*

Fig. 6. Mt. Asgard, 6,596 feet, seen from Mt. Battle, 4,420 feet. Turner Glacier to the right.

tion against erosion while rivers continued for a time to carve the valleys. Later ice streams occupied and further modified these valleys. Presuming that the interglacials, if they occurred here, were as warm or warmer than the present climate, it seems likely that rivers have occupied the large valleys, such as Pangnirtung Pass, for at least as long as have glaciers and Thompson gives them the credit for most of the excavation rather than the moving ice. The writer believes to a certain extent in the protection hypothesis for ice and the carving of valleys and fiords as due not only to ice, but also to water action in rifts formed by yielding of the bedrock to vertical forces.

Research work has also been carried out on the ice shelf off the northernmost coast of Ellesmere Island, a most interesting glaciological phenomenon. The ice islands in the Arctic Ocean, which have been broken off from this shelf are readily recognizable from their size and shape and have yielded much information on the currents and the slow clockwise eddy that exists here (Koenig and others, 1952). One of the islands was occupied by the U.S. Air Force for twenty-five consecutive months, and studies were made by scientists from the Air Force Cambridge Research Center. They found among other things rock piles on the surface and more than fifty layers of dirt

and mud in a 52-foot hole (Crary and others, 1952). The ice shelf, which is about 10 miles wide west of Cape Columbia (Hattersley-Smith and others, 1955, p. 4) occupies fiord mouths and open coast. It has a peculiar rolled surface not yet satisfactorily explained, which was commented upon by early travellers such as Aldrich and Peary. A similar formation, the "Sikussak" has been described in northwest Greenland by Koch (1926, p. 100). Debenham (1954) has speculated on the method of origin of the ice shelf and many of his ideas were proved well founded by Hattersley-Smith. They agree that the shelf grows from below by freezing sea water rather than from above, as normal ablation seems to remove all the annual snow cover plus a few inches of ice (24 inches were lost in 1954 which was an unusually warm summer in the Canadian Arctic). But the shelf is up to 150 feet thick, the same as ice island T3, and water depths of over 980 feet were found off the northwest edge. Thus Debenham's gently shelving coast is not valid, nor his idea of the ice being more or less continuously aground. A narrow tide crack was present between ice and land which could, by freezing each winter, produce lateral pressure to account for the surface rolls in fiords. The writer, however, does not agree that the Arctic Ocean pack ice forms the compressive agency on the open coast sections. For one thing, the hole in the shelf left by the break off of an island in 1946 is now covered by 20 feet of ice, but *unrolled* ice. Perhaps the rolls are due to some differential snow-drift ablation. Similar features have appeared on Ellesmere Island lakes (Montgomery, 1952, p. 187) and the melting pattern seen by the writer on temporary sea ice in Clyde Fiord, is suggestive.

One great problem is why the ice should be so thick here compared with the open sea pack. Presumably it needs calm water, preferably stagnant, and low temperatures. The water is kept calm by the pack offshore. The mean annual air temperature is very low (around -20°C) and the thick ice at depth will presumably be about this temperature and able to extract heat from the sea below. But why should the new growth fill up the hole in the shelf edge, at nearly 3 feet a year? Hattersley-Smith believes that the shelf has formed since the climatic optimum a few thousand years ago (Hattersley-Smith and others, 1955, p. 23). The dating of driftwood found in the ice by the Carbon 14 method should give further information.

In southern Baffin Island Mercer studied the Grinnell ice cap and, briefly, its southern neighbour, Terra Nivea, in 1952 and 1953. On each occasion his stay was much less than the full ablation season, but the two successive summers showed interestingly dissimilar conditions. The Grinnell has eight outlet glaciers in the north and east, four of which reach Frobisher Bay. All of these are in retreat or stationary, but on the south a broad lobe which terminates at about 1,000 feet above sea level was advancing over mature heath vegetation. Mercer found superimposed ice and firn on the summit domes which nowhere rise above 2,860 feet (Mercer, 1954).

He investigated particularly the raised strand lines in the region and believes the highest stands at 1,425 feet. It is always hard to be certain that such strand lines are old sea levels. Such an elevation could have occurred

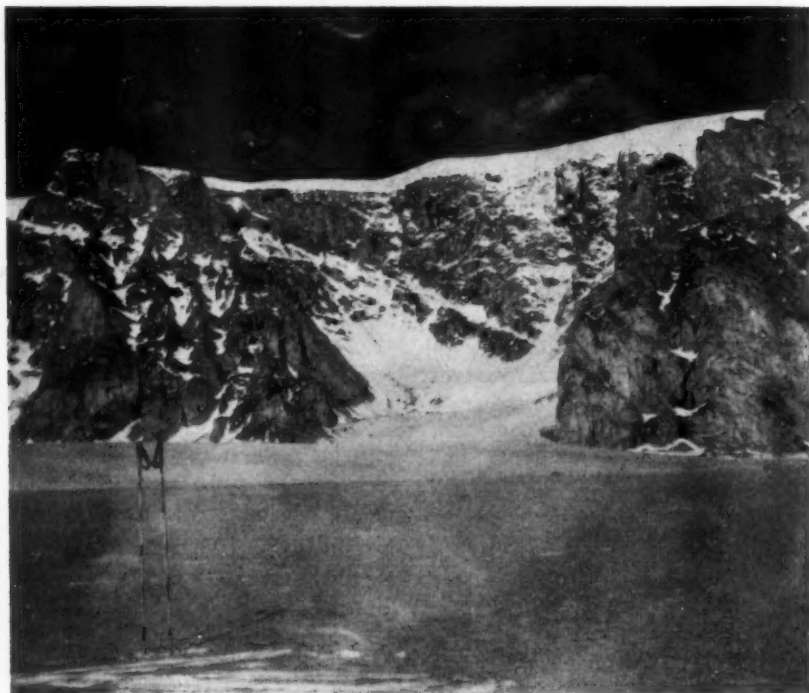
since the ice load was removed. Mercer believes that during the Pleistocene this area must have been starved of precipitation. Today, however, precipitation is high in this area and there are very low summer temperatures and much summer fog.

Returning to the general picture and budgetary state of the Canadian arctic glaciers. Recession is marked in Pagnirtung Pass, 200 to 300 yards on one tributary glacier between 1925 and 1948, but little since then. It is also marked in Frobisher Bay, with the exception noted above; it is, however, very limited on the Barnes Icecap and the contiguous coastal zone, and also in Bylot Island and southern Ellesmere. In the Grant Land "quarter" recession appears to be appreciable, possibly due to lack of precipitation rather than to increased ablation.

From the slender evidence available there appears to be great variation in the height of the firn line instead of any uniform poleward decline. It stands at only 2,150 feet on the Frobisher glaciers, but is about 5,000 feet on Cumberland Peninsula and probably not far below that on the other Baffin coastal mountains and on Bylot Island. The equilibrium line was at 2,600 feet on the inland Barnes Icecap. Much more work is necessary before good reasons for this variability can be given. It should be remembered that temperature lapse rates are unusual in the Arctic where deep winter inversions are frequent; however, ablation season drop in temperature with altitude is fairly normal and annual mean temperatures at sea level are between -8°C in Frobisher Bay to -20°C on Ellesmere Island (Rae, 1951, p. 41).

Examining Flint's hypothesis of the Baffin-Labrador origin of the American ice sheet (Flint, 1943), all the evidence so far points to a large and prolonged uplift of the Baffin rim, on which ice might have grown sufficiently to spill westward and then by its own nourishment momentum grow still farther. The writer finds it hard to account for the moist air masses sufficient to keep this momentum on the growing southwest edge, but given their presence, a growth from this uplifted region seems feasible. Retreat by stages with persisting ice domes distributed around in Hudson Bay, Ungava, and probably last of all in Foxe Basin, again seems likely. More detailed work comparable with the Scandinavian work on retreat is required.

Bird has already done some useful work towards this in Keewatin where he finds lake levels in the Dubawnt River basin up to 800 feet, presumably dammed by Hudson Bay ice to the east, and finally an old sea level 360 feet above that of today, representing the moment when this Hudson Bay ice retreated sufficiently to let in the ocean (Bird, 1951, pp. 22-3). Foxe Basin is now a shallow area still probably undergoing upward recovery. On the low limestone islands now emerging from the sea there must have been one of the last ice centres. In 1950 Goldthwait found strong evidence of southwest-northeast ice movement in the area south of the Barnes Icecap, a movement as if from such a source region (Goldthwait, 1951, p. 568). The writer finds the Barnes itself difficult to explain except as the last relic of a final ice dome, comparable to the relics in the late Pleistocene time in the Swedish lake district, at present slowly migrating northeastwards, in approximate

*Photo: W. H. Ward***Fig. 7.** Corrie and edge of ice cap seen from "Concordiaplatz".

equilibrium with present climate, and maintaining itself by its own great cold. One little side problem—could the lack of musk ox remains in Baffin Island be due to the very recent lingering of the Foxe Basin-Baffin ice, and the chance that the musk ox and its enemy, man, arrived at the same time?

The Canadian Arctic region is an excellent area for examining problems of the erosive and protective powers of high polar glaciers and of the origin of fiords. The evidence from Baffin shows well the protective power of small ice caps and highland ice sheltering the mountain and plateau tops, while erosive forces attack their flanks and the valley floors (Fig. 7). The power of glacier melt streams to down-cut strongly in a region where uplift is continuing, can be seen and compared with the down-cutting and valley-widening powers of the ice streams themselves (Chamberlin and Chamberlin, 1911).

The peculiar S-shaped fiords of the region show the type of tearing and faulting that might be produced by the uplift and stretching of these hard Precambrian rocks. Once again it seems that rifting and water erosion in the rifts were as important (Gregory, 1913) as down-cutting by the ice, which undoubtedly filled them deeply.

Little is yet known of the bathymetry of the Canadian fiords. Baffin Bay itself seems to be a downfaulted depression alongside the upfaulted coast line of Baffin Island. We do already know, however, that on the opposite coast the west Greenland fiords are rather curiously shallow in comparison with some of the great Norwegian and western American depths (Dunbar, 1951, pp. 20-7), despite the great thickness of ice inland of them and the rapid movement of outflowing ice streams.

Altogether this is a region of splendid glaciological opportunity, a region of great and violent forces and a source of factual evidence for the great controversies on the subject of the origin of the ice sheets and of their effects on the terrain.

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STRUCTURAL AND STRATIGRAPHIC STUDIES OF THE NORTHERN ELLESMERE ICE SHELF

Ernest W. Marshall*

THIS paper reports on an aspect of the glaciological program carried out on the ice shelf of northern Ellesmere Island in 1954 that was not described previously by other members of the expedition.¹ The glaciological program of the expedition to northern Ellesmere Island was supported by the Snow, Ice and Permafrost Research Establishment, Corps of Engineers, U.S. Army, to correlate with structural and stratigraphic studies conducted on ice island T3 during the period May to November 1953. Glaciological investigations were conducted principally around Ward Hunt Island, where the largest remnant of the once more extensive ice shelf exists today. The structural and stratigraphic relationships of the various ice components of the shelf were investigated because the Ellesmere ice shelf is probably the primary source area of the ice islands of the Arctic Ocean. Also, the climatic history of the area during the past periods of ice shelf formation can be deduced from these studies.

Ice cores, 3 inches in diameter, were obtained with a manually operated hand corer at selected sites on the ice shelf (Fig. 1) and in adjoining fiords and ice fields. The aluminum corer, drill rods, and tripod were of a size and weight adapted for sledge transport (Fig. 2) and for back-packing where necessary. When taking shallow cores, down to depths of 10 to 15 feet in iced firn, the rods and corer were easily hand hauled. In deeper coring, to overcome the weight of the corer and rods plus a partial vacuum created beneath the corer, a manually operated hoist was used consisting of block and tackle suspended from an aluminum tripod (Fig. 3). With similar coring equipment aided by a gasoline driven winch, a hole was cored by hand to a depth of 106 feet on ice island T3 in 1953. Cores were collected on sledge and ski trips and tentatively classified as the core site by visual examination. While on extended sledge trips cores were brought back to the trail camp for examination. Selected portions were returned by sledge to the Ward Hunt base camp for detailed study; here thin sections of the 3-inch cores were examined and photographed in polarized light. Four ice types, iced firn, glacier ice, lake ice, and sea ice, were identified as components of the ice shelf

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¹See also Hattersley-Smith, G. and others. 1955. "Northern Ellesmere Island, 1953 and 1954". *Arctic*, Vol. 8, pp. 3-36.

by means of their characteristic textures seen in the sections and by field observations during the period of bare ice.

These investigations indicate that the thick primary portion of the Ellesmere ice shelf is composed stratigraphically of three major ice units. Two of these units were observed, the third is postulated, and was not encountered at the surface or in cores down to the depth of 80 feet. Seismic measurements of the ice shelf by A. P. Crary, U.S. Air Force Cambridge



Fig. 1. Petrologic field examination and photography of thin sections of ice from McClintock Bay. Marshall examining 3-inch ice core obtained by aluminum hand auger.

Research Center, indicate a total thickness of approximately 150 feet (Hattersley-Smith and others, 1955, p. 28).

The upper unit of the ice shelf is a sedimentary section of granular iced firn with grain diameter averaging about 1 cm. Interstratified lenses of lake ice of typical columnar structure, represent local, and in some cases widespread, ponding of meltwater during the latest period of ice shelf formation. The annual accumulation of this iced firn section was found to be approximately 3 inches per year, on the basis of vertical changes in grain size, together with the stratigraphic position of dust layers. This upper unit was observed at depths of 80 feet. It rests unconformably upon a middle unit which is also composed of granular iced firn with associated lenses of lake ice, but which has been soaked by migrating sea water. The ice surface along the depositional unconformity is marked by a widespread, heavy dirt layer, and near land areas

by patches of associated gravel and sharp, irregular, avalanched rocks. The insolation received by bedrock areas along the mainland and around islands protruding through the ice shelf, warmed up the surrounding air, and has caused the accelerated ablation of the upper iced firn unit, so that the middle ice unit with its heavy dirt layer is revealed. The sedimentary nature of the middle unit is most evident on the weathered granulated exposures of the salt water-soaked iced firn. Unweathered exposures do not show such evident

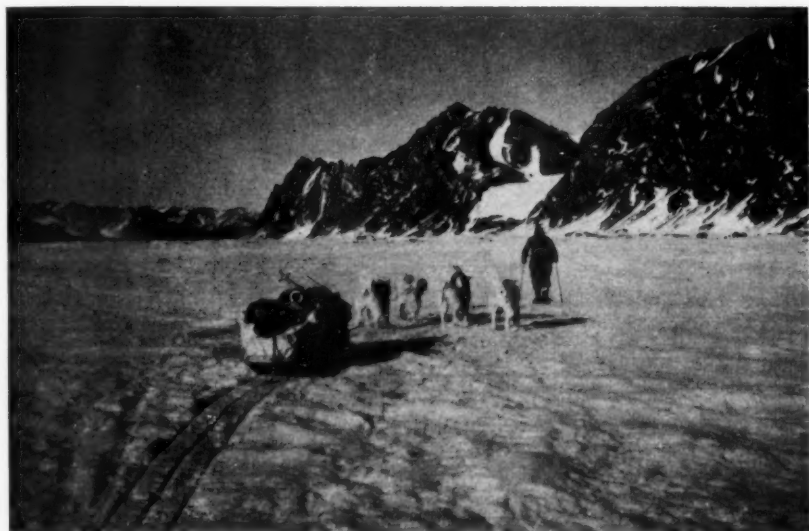


Fig. 2. Geologic and glaciological investigation of M'Clintock Bay by Christie and Marshall, June 1954. Food and scientific equipment carried on dog-hauled pulka.

stratigraphy. In most of the exposures the contact between the salt water-soaked and unsoaked iced firn coincides with the unconformity, but sometimes the salt water soaking of the iced firn extended above the unconformity into the overlying younger iced firn.

Since the lowest observed stratigraphic unit of the ice shelf fringing the coast is sedimentary, a primary basement or platform is postulated, upon which the oldest iced firn accumulated. Such basements exist at the margins of the ice shelf and in fiords behind, and serve as a platform for iced firn deposition during the cooler years of the present climatic cycle. This situation was observed in cores taken in the ice shelf re-entrant opposite Markham Bay, from which a section of shelf broke away in 1946 (Koenig and others, 1952, pp. 76-7). This re-entrant, refilled by the normal freezing of sea water and the rafting of sea ice, showed iced firn accretion in the upper 1 foot of core.

In some of the fiords behind the ice shelf which receive huge quantities of meltwater during the summer, the typical ice shelf structure has disappeared due to accelerated bottom melting and subsequent fragmentation. In these areas sea ice and lake ice structures cover the fiord and are a function of the salinity of the surface waters at the time of freeze up.

Evidence that glacier ice serves as a basement for iced firn accumulations was also found on the west shore of Markham Bay, where a local ice field



Photo: R. L. Christie, Geol. Surv. Can.

Fig. 3. Marshall coring on Ward Hunt Island ice field. Aluminum tripod breaks into 5-foot sections for ease of sledge transport.

merges with the ice shelf structure of the fiord. Portions of the ice shelf in Markham Bay have been destroyed by the ablation of meltwater, other portions have been thinned, and fractures due to tidal and wind stresses reveal ice cliffs 10 to 15 feet high, in which the ice structure could be seen. These exposures show a basement of glacier ice upon which there is up to 10 feet of iced firn. A study of aerial photographs, together with this field evidence suggest that frequently the basement accumulation was created by tributary glaciers coalescing within the fiords. Coring and surface observations in the Ward Hunt area of the ice shelf give no evidence that glacier ice is the primary basement of the ice shelf fringing this portion of the coast (Fig. 4). It is assumed that sea ice interfingering with the glacier ice or lake ice cover of the fiord provided the original basement. Thermal studies by Crary indicate that small increments of brackish or salt ice may possibly accrete on the bottom of the ice shelf (Hattersley-Smith and others, 1955, p. 30).

The initial shelf building period began with the formation and persistence of a platform of deposition upon which the iced firn gradually accumulated. As accumulation continued, the primary basement and the superimposed iced firn were depressed into the sea water, and salt water penetrated upward along intergranular channels to levels determined by the 28.5°F isotherm, the freezing point of the sea water. Both the total thickness of the iced firn deposited during the first period of shelf building, and the upper limit to which the salt



Fig. 4. Looking west across shelf ice to Ward Hunt Island from east side of mouth of Disraeli Bay.

water penetrated are unknown. Subsequent warming of the climate caused the complete ablation of the upper, unsoaked iced firn and unknown thicknesses of the section were penetrated by sea water. This ablation surface is marked by a major dirt layer due to dust layers deposited in the upper section of the iced firn and concentrated by ablation, in addition to wind blown material from adjacent land areas.

In the second, or latest period of shelf building new iced firn formed to a thickness of at least 80 feet, as proved by coring. These new accumulations were sufficient to depress the ice shelf even lower into the sea and the salt water migrating to the 28.5°F isotherm rose above the unconformity into the younger iced firn.

The present amelioration of the climate of the Arctic is indicated by the dirt layer now forming on the surface of the ice shelf as a result of prolonged ablation.

These structural and stratigraphic studies of the Ellesmere ice shelf have provided information on the structure of areas of potential ice islands and outlined the broad climatic conditions under which the present ice shelf formed. A maximum age of the northern Ellesmere ice shelf may be obtained from the Carbon 14 dating of drift wood found behind the ice shelf during the summer of 1954. The age of the organic-rich dirt from the unconformity could provide a date for the last great warming of the arctic regions. Stratigraphic and petrologic studies of ice cores collected from ice island T3 and the Ellesmere ice shelf now in progress at the Snow, Ice and Permafrost Research Establishment laboratories will provide more details of the formation, growth, and disintegration of ice shelves bordering the Arctic Ocean.

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SOME ASPECTS OF THE DISTRIBUTION OF MICROFAUNA IN THE ARCTIC

Marie Hammer

KNOWLEDGE of the composition and distribution of the microfauna of Greenland and arctic North America has slowly accumulated during the past twenty years. By 1944 when the study of the microfauna collected by the expeditions of Knud Rasmussen, Lauge Koch, and others was completed (Hammer, 1944), the microfauna of Canada was still unknown, there was no apparent relationship between the microfauna of the United States and Europe, and it was not possible to deduce the origin of the Greenland fauna. Since then investigations have been carried out in northern Canada, including Ellesmere Island, in Alaska, and in Peary Land, and Søndre Strømfjord in Greenland. These have shown that the two groups of animals discussed in this paper, the oribatids and the collembolans, are well suited for zoogeographical studies; their distribution may settle the problem of the origin of the true fauna of Greenland, as these non-mobile animals which belong to the soil have little chance of straying from their particular biotope.

Previous research workers found that some of the animal groups in Greenland originated in North America, whilst others came from Europe. All these animals were, however, mobile and could travel long distances, either alone or with external help. Mammals crossed the ice from North America; birds flew to Greenland from both Europe and North America; some insects, such as butterflies, came from North America across the narrower straits, while others crossed the sea, partly unaided, partly carried by air currents. Some spiders must have travelled in this way, while others must have survived the Ice Age in Greenland. This interchange of fauna took place in both warm and cold climatic periods and is still continuing. Thus Greenland has obtained a very varied fauna from which the exotic elements have gradually disappeared or have found refuge in remote valleys or on mountains, depending on their requirements.

It seems unlikely that the elements of the microfauna have spread in this way as they are earth-bound and belong to the soil. The narrow sphere to which each is restricted is well shown from another part of the Arctic. At Yellowknife, 5 samples were taken from each of the two biotopes in a cushion of alternating lichens and *Polytrichum*, about one square metre large, growing on a flat rock. The *Polytrichum* harboured a collembolan species, *Lepidocyrtus violaceus* (Geoffroy), of which 11 individuals in all were taken in 3 of the 5 samples; the lichen biotope, however, contained another *Lepidocyrtus* species, *L. cyaneus* Tullb. var. *albicaudatus* Hammer, of which there were 34 individuals distributed throughout the 5 samples; this species was not found elsewhere in Canada.

In no case was the species characteristic of one biotope found in the other, although the two vegetation types were growing together. The remaining collembolan fauna was rather varied. Such intense specialization does not necessarily prove that these animals never leave their own biotope although this is unlikely to happen, and it might prove fatal to many species.

Figure 1 shows areas in which microfauna have been collected with a Berlese funnel. Thule, Frobisher, and northern Quebec should probably be omitted, as practically no animal life was found and the sampling was presumably erroneous. About 750 samples have been taken from Greenland. Alaska and northern Canada have been less closely studied and a total of only 670 samples has been obtained. Greenland is poorer in species, as might be expected because of the more homogeneous conditions and the isolation; about 65 species of oribatids and 50 species of collembolae are known.

The oribatid and collembolan fauna of Canada and Greenland are compared in Figs. 2 and 3, according to the distribution of the species. No less than 86.5 per cent of the oribatid fauna of Greenland is known from Europe (Hammer, 1952a, p. 82) and 44.1 per cent from Canada and Europe. In Canada 55.6 per cent of the oribatid fauna is common to Europe, and 24.5 per cent has also been found in Greenland. The oribatid fauna of both Greenland and Canada thus corresponds closely to that of Europe. The circumpolar species in both countries are the same. There are 2 species found in Greenland only, *Jugoribates gracilis* Sell. and *Belba trågårdhi* Grav. and 38 species so far found in Canada only. A few of the species found in Canada had previously been found in the United States only.

Similarly a comparison between the collembolae of Canada and Greenland (Fig. 3) shows that 84.8 per cent of the collembolan fauna of Greenland is known from Europe (Hammer, 1953a, p. 80) and 58.7 per cent has also been found in North America. Only 54.7 per cent of the Canadian collembolan fauna is known from Europe and 28.9 per cent

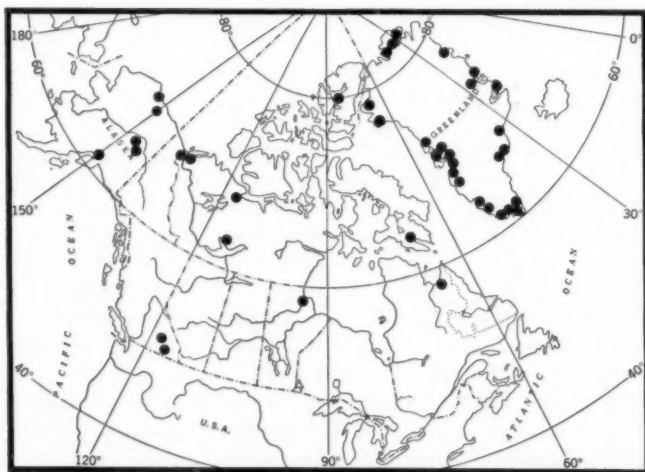


Fig. 1.
Areas in
which
microfauna
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funnel.

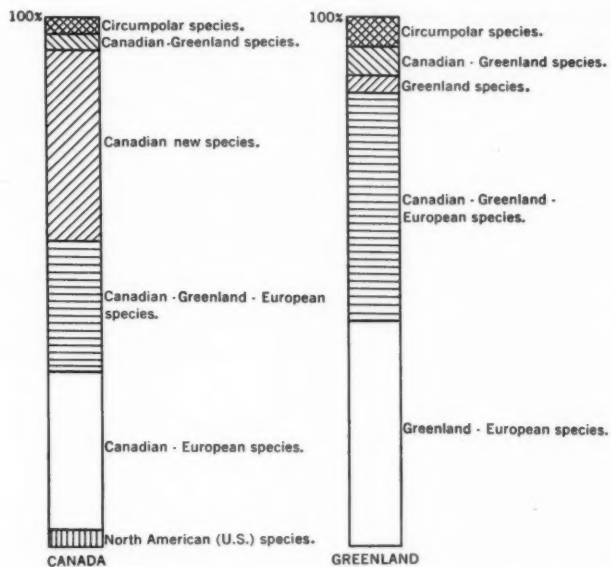


Fig. 2. A comparison between the oribatid fauna of Canada and Greenland.

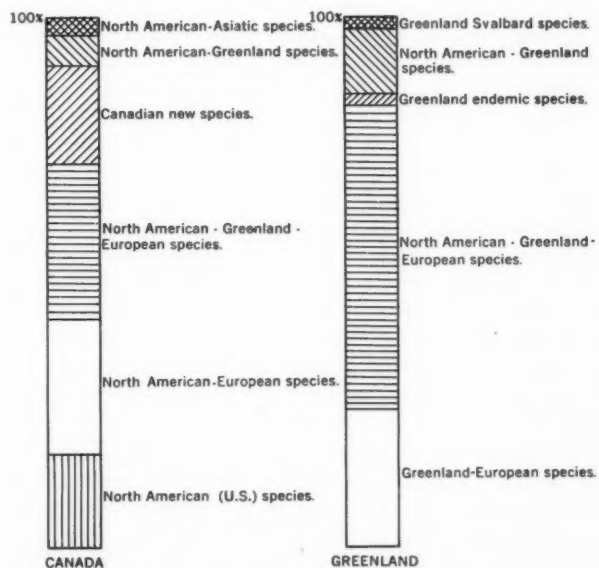


Fig. 3. A comparison between the collembolan fauna of Canada and Greenland.

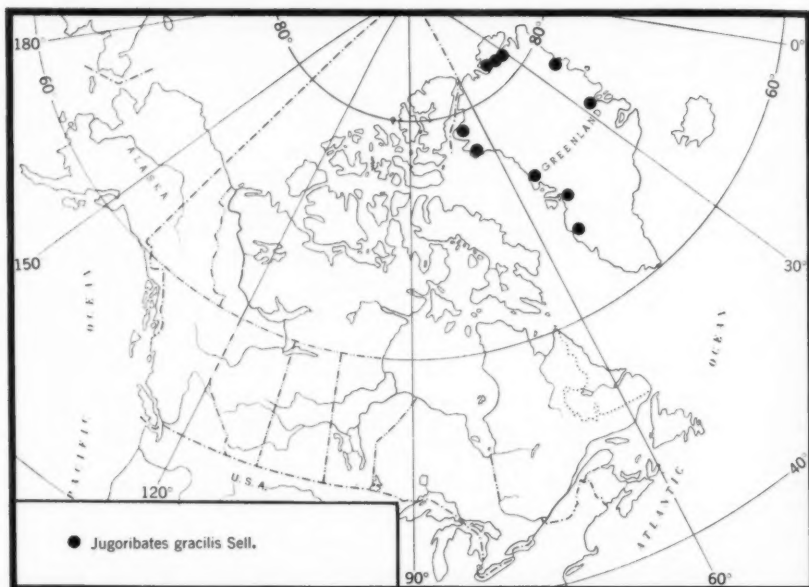


Fig. 4. Distribution of *Jugoribates gracilis* Sell.

is also found in Greenland. A small group of species is common to North America and Greenland only. Greenland has a small percentage in common with Svalbard and Canada has an equally small percentage in common with Asia. Both Canada and Greenland have some species that are restricted to the one country. In Canada this group comprises 19.5 per cent of the total. In addition, 17.6 per cent of the Canadian collembolus are also known from the United States.

The greater part of the microfauna of Greenland is common to Europe and Canada. As knowledge of the microfauna of Canada and Greenland is extended this percentage will presumably increase but the ratio is unlikely to change materially. Europe, Greenland, and northern North America thus form a single, large, very old faunal area, which was an entity when the animals occupied it. Since then there have been many changes and the animal life has had to adapt itself to periodic climatic fluctuations. For example, the comparatively rich microfauna in the moist valleys of southern Greenland must be considered a relic fauna from a warmer period. Elsewhere in Greenland other climatic changes have also left their mark on the fauna.

Among the oribatids, *Jugoribates gracilis* has been found in Greenland only and its range is indicated in Fig. 4. It is widespread in Peary Land (Hammer, 1954, p. 21) where it is the commonest oribatid and is particularly numerous in fell-fields¹ and similar dry biotopes. It is also known on the east coast of Greenland, from Mørkefjord in about 77°N. (Hammer, 1954,

¹Rocky barren ground with scattered cushions of small plants.

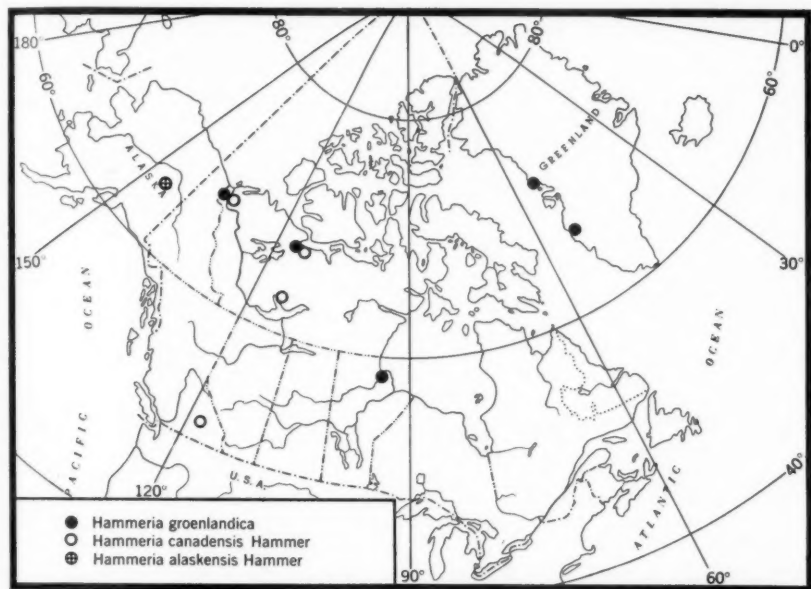


Fig. 5. Distribution of the genus *Hammeria*.

p. 22) and from Ymers Ø in the Keiser Franz Josephs Fjord area (Hammer, 1946, p. 21). On the west coast it has been found in Inglefield Land, 79°N., at Kanak, and at Upernavik. Farther south it is known from Disko Bugt (Strenzke, 1952, p. 96), and the desert-like interior of the Sønder Strømfjord area (Hammer, 1952b, p. 410). In all these areas precipitation is low: about 125 mm. in Peary Land, 110 mm. on Ella Ø, 120 mm. in Sønder Strømfjord, and 230 mm. at Upernavik. This oribatid must, therefore, be considered a relic from a former period when the climate was much drier. It is still questionable whether *J. gracilis* is really endemic to Greenland. A comparison with other species suggests that it may also live in the northernmost Canadian islands, and perhaps in Alaska.

The genus *Hammeria* (Fig. 5) was first found in west Greenland near Upernavik, where Sellnick described *H. groenlandica* (Hammer, 1944, p. 46) in fell-field and moor vegetation. Recently it has been found in the arid, inner part of Sønder Strømfjord (Hammer, 1952b, p. 410). In Canada *H. groenlandica* is known from arctic localities such as the Richardson Mountains, Coppermine, and Churchill and only from the driest biotopes (Hammer, 1952a, p. 52). Another species of the same genus, *H. canadensis* Hammer, has been found in Canada together with *H. groenlandica* at Coppermine, Reindeer Depot, and farther south at Yellowknife, and in the Rocky Mountains (Hammer, 1952a, p. 53). This species is also found in bogs. A third species, *H. alaskensis* Hammer (Hammer, 1955, p. 22) is known from Alaska, and other closely related species, *Pelops minnesotensis*, *P. latipilosus*

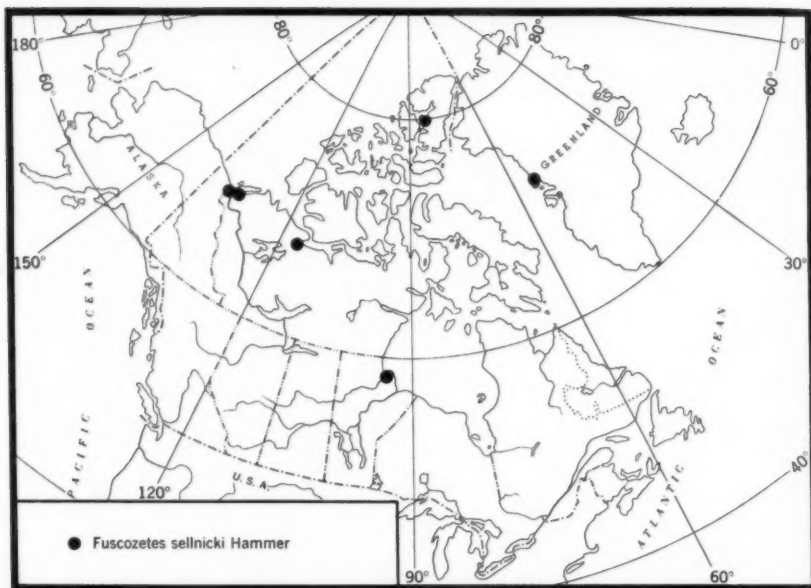


Fig. 6. Distribution of *Fuscozetes sellnicki* Hammer.

and *Eupelops monticolus* have been described from the United States by Ewing. The whole genus is thus markedly American, a single species having spread to west and southwest Greenland, where, like *Jugoribates gracilis*, it is perhaps a relic from a warmer and drier period.

Fuscozetes sellnicki Hammer (Fig. 6) has been found in Canada in the Richardson Mountains, at Reindeer Depot, Coppermine, and Churchill, mainly in wet moss, but also in heath biotopes. A single individual was found on Ellesmere Island in a cushion of *Stellaria* sp. In Greenland it is known only from Upernavik, a few individuals having been taken from bogs or bog-like biotopes, and two individuals from heath vegetation.

In Greenland *Peloribates pilosus* Hammer is known from Ella Ø where it is found on lake banks, in great numbers in a bog, and occasionally in heath vegetation. *P. pilosus* is rather common in the interior of Søndre Strømfjord in heath vegetation. Three individuals have been found in Canada, at Churchill, in a thin layer of moss. So little is known about the distribution of this species that no conclusions can be made as to the routes or way by which it spread. Another species of the same genus, *P. canadensis* Hammer, is known from Canada and Alaska; and a third species *P. alaskensis* Hammer (Hammer, 1955, p. 18) is known from Alaska (Fig. 7).

Eremaeus translamellatus Hammer (= *E. oblongus* C. L. Koch borealis n. subsp.) has only been found in Greenland in the Disko Bugt area (Strenzke, 1952, p. 94). In Canada it is known from moor vegetation, lichen heaths, and similar biotopes in the Richardson Mountains, at Reindeer Depot, and at Coppermine (Fig. 8).

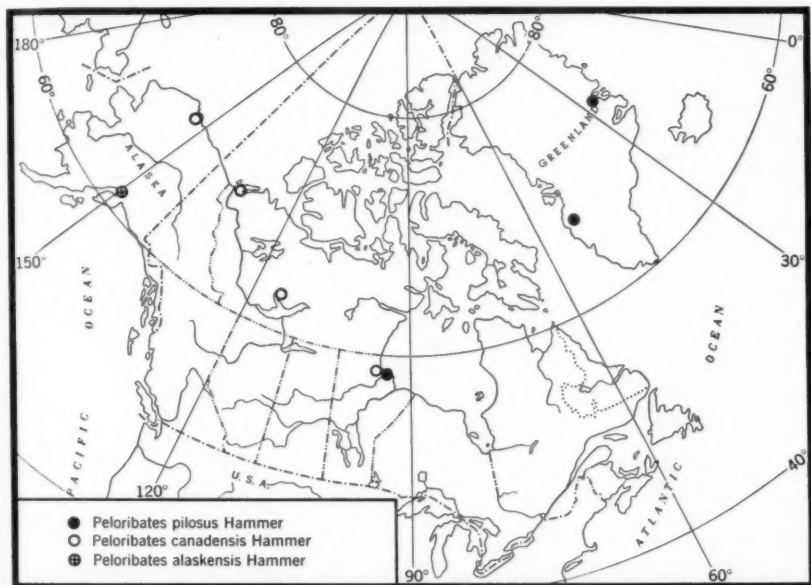


Fig. 7. Distribution of the genus *Peloribates*.

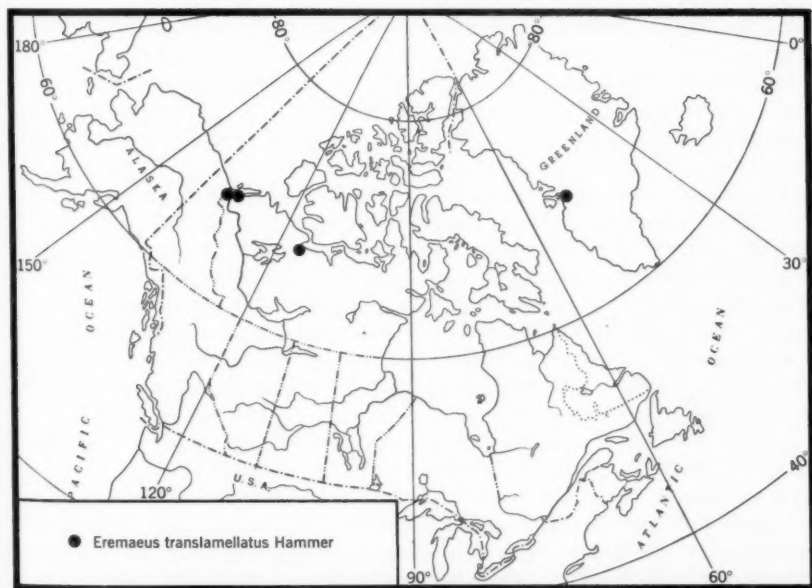


Fig. 8. Distribution of *Eremaeus translamellatus* Hammer.

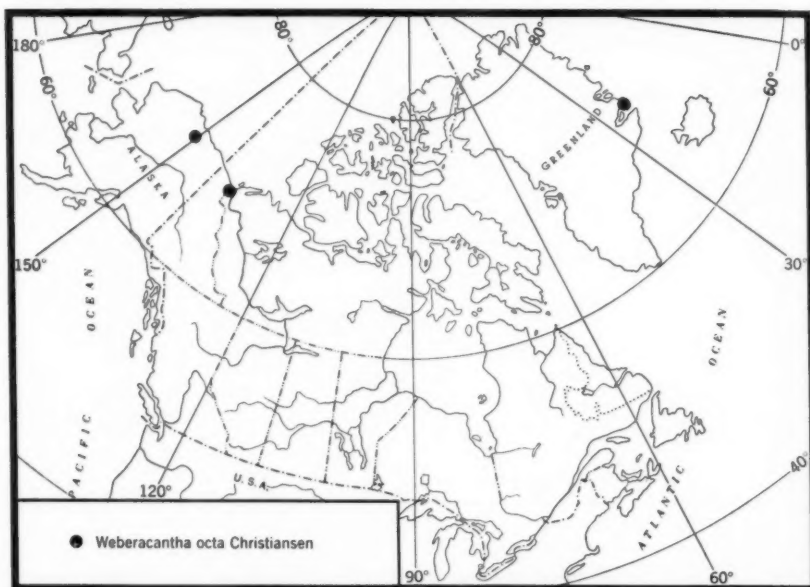


Fig. 9. Distribution of *Weberacantha octa* Christiansen.

This account deals with the large and distinctive genera only and none of the species described has been found in Europe. The smaller genera such as *Brachychthonius*, *Suctobelba*, and *Oppia* are still relatively unknown and are so easily confused that their distribution cannot yet be discussed. However, it should be mentioned that *O. clavigera* Hammer, which has been found in lichen vegetation at Reindeer Depot, Coppermine, and Churchill in Canada, is comparatively numerous in Peary Land in a desert climate.

Certain highly specialized collembolan species show a distribution pattern in Canada and Greenland similar to that of the oribatids. Only a few species which can readily be identified are included.

Weberacantha octa Christiansen has been described from Alaska and from heath vegetation in the Richardson Mountains of northwestern Canada. Unlike most of the oribatids discussed, this characteristic collembole has not been found elsewhere in northern Canada, and in Greenland it has only been collected from Scoresby Sund in the extreme east (Hammer, 1953a, p. 82) (Fig. 9).

A new *Folsomia* species, *F. regularis* Hammer was recently found in a bog on Ellesmere Island. It has now been discovered in Peary Land where it was found on snow patches and in moss (Fig. 10).

When the distribution maps of species which occur only sporadically in Greenland are examined, it appears that these species must have come to Greenland by way of the Canadian arctic islands, where apart from a few

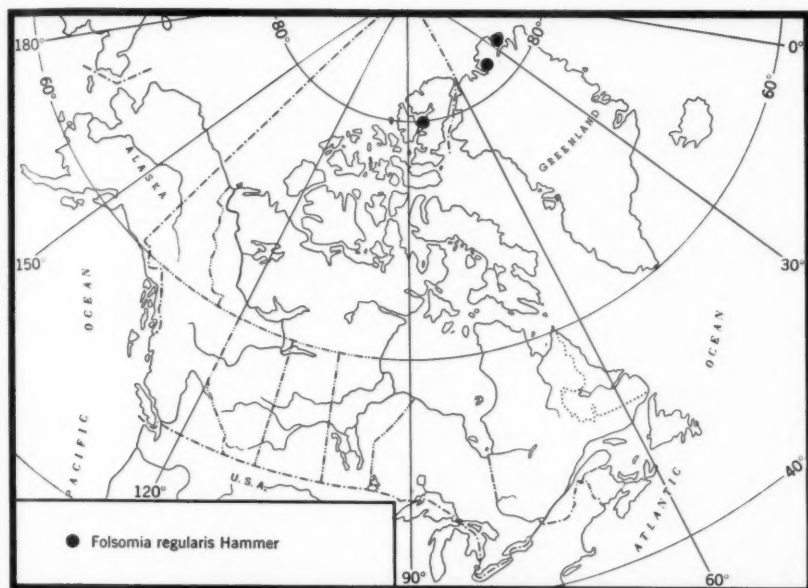


Fig. 10. Distribution of *Folsomia regularis* Hammer.

samples from Ellesmere Island, practically no collections have been made. None of these species has been found south of Scoresby Sund in east Greenland or south of Disko Bugt in west Greenland—apart from the interior of Søndre Strømfjord, where special climatic conditions prevail. The distribution pattern shows that these species do not tolerate the moist, oceanic climate of south Greenland. Unfortunately the Blosseville Kyst has not been investigated, and it is not possible to show that the climatic boundary is at about 68°N. , as suggested by Degerbøl (1937) from other faunal studies. As Greenland, particularly on the east coast, has been studied more closely than any other northern area, it seems more and more certain that these species are not found in Greenland south of 70°N. , but that they have a northern distribution. A few species including *Fuscozetes sellnicki* seem to be distributed from the northern coast of the Canadian mainland by way of Ellesmere Island to west Greenland. This pattern probably exists or existed for the other species mentioned. In some cases the continuity may have been broken by climatic changes so that there are now two widely separated distribution areas, as in the case of *Weberacantha octa* (Fig. 9).

These species, found sporadically in Greenland but which are widespread in northern Canada often with other species of the same genus, must be considered American—as long as nothing is known of their occurrence in Asia—and presumably emigrated to Greenland at a late date (interglacial or postglacial). The large group of species found in Greenland, which is

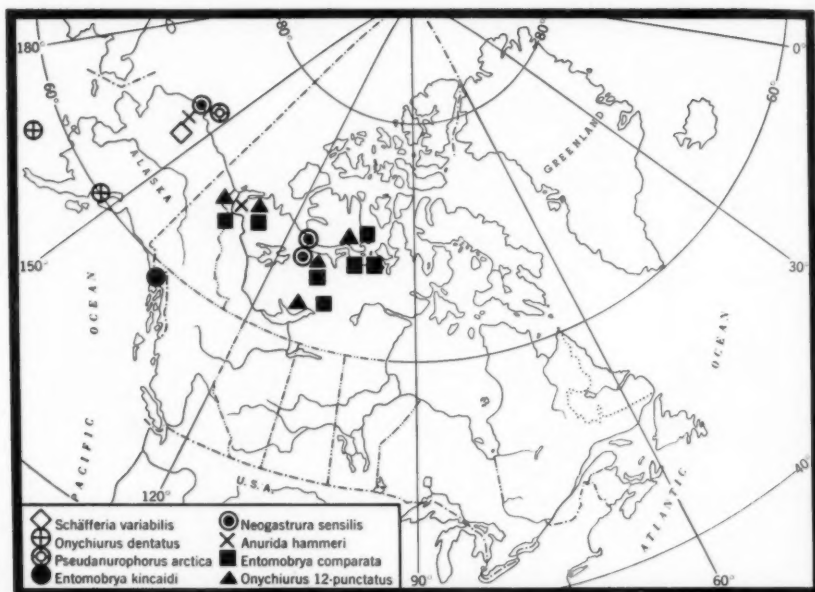


Fig. 11. Distribution of collembolan species known only from Alaska and northwestern Canada.

common to North America and Europe probably survived the Ice Age in Greenland.

There is no doubt that future research in the northern Canadian islands and northern Greenland will produce additional discoveries. For example, recently in a few Berlese samples from Ellesmere Island a collembole, *Proisotoma mackenziana* Hammer, was found which previously was only known from the Mackenzie delta. A new oribatid species, *Trichoribates polaris* Hammer was taken in the same material from Ellesmere Island, and has now been found in Alaska also (Hammer, 1955). In Greenland another oribatid, *Belba groenlandica* Hammer was found in Inglefield Land and has now been collected in Peary Land, where a new collembolan species, *Micranurida polaris* Hammer has also been found.

A number of collembolan species have been taken in Alaska and the northwest of Canada which have not so far been discovered anywhere else. These species are: *Neogastrura sensilis* (Folsom), *Schafferia variabilis* Christiansen, *Anurida hammeri* Christiansen, *Onychiurus 12-punctatus* Folsom, *O. dentatus* Folsom, *Pseudanurophorus arctica* Christiansen, *Entomobrya kincaidi* Folsom, and *E. comparata* Folsom; the distribution of these species is shown in Fig. 11. It must be assumed that as the majority of these species are comparatively large and distinctive, they are not widespread in North America where J. W. Folsom, the authority on collembolus, has worked for many years.

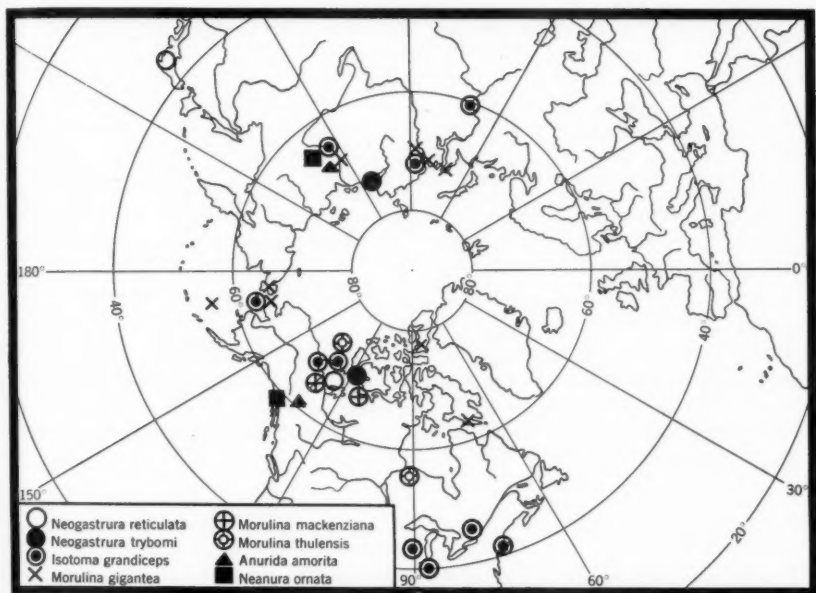


Fig. 12. Distribution of collembolan species known only from Asia, Alaska, and northern Canada (*Isotoma grandiceps* Reuter also known from the United States).

A few collembolan species have long been known from Siberia and Japan, and from some islands in Bering Strait. They are also found in Alaska and other parts of North America (Fig. 12). *Neogastrura reticulata* (Börner) has been found in Japan and the Mackenzie delta, *N. trybomi* (Schött) in northernmost Siberia and the Mackenzie delta, *Anurida amorita* Folsom and *Neanura ornata* Folsom are both known from Siberia and Alaska. In North America these four species have not been found east of the Mackenzie delta.

Some species have, however, spread farther east; *Morulina gigantea* (Tullb.), which is known from Siberia and islands in Bering Strait, has been reported from Baffin Island and Ellesmere Island, though there is some doubt about this identification. There are two other *Morulina* species in Canada, *M. mackenziana* Hammer known from the Mackenzie delta, and *M. thulensis* Hammer known from the Mackenzie delta and from Churchill. It is possible that the doubtful *M. gigantea* reported from eastern Canada is one of these species. In North America, as Fig. 12 shows, the *Morulina* species are only found in the north. *Isotoma grandiceps* Reuter, on the other hand, which is also found in northern Siberia, Bering Strait, and the Mackenzie delta, reaches the more southerly parts of North America. Both these collembolan species are probably Asiatic in origin and have emigrated to Alaska by way of Bering Strait, but while *Morulina* has spread farther east, *I. grandiceps* has penetrated south into the United States.

It is not known why these large-sized species have failed to reach Greenland. A species of *Morulina* has, however, been found as far east as Ellesmere Island. A possible explanation is that the coldness and, particularly the dryness of the climate in the Canadian Arctic Archipelago and northwest Greenland, are a barrier to the farther eastward migration of the microfauna. This hypothesis is supported by investigations in Peary Land which show that in areas that are bare of snow in winter the fauna is extremely poor compared with the richer fauna in areas covered by drifted snow. It is also possible that the soils of Greenland are not rich enough to support these comparatively large-sized species.¹

Most of the species discussed were found on the edge or immediately north of the tree-line in western Canada. Here, the summer temperature is far higher than on the migration route through the Canadian arctic islands to Greenland. But if cold summers along the migration route have prevented entry into Greenland, why have the species not penetrated southwards? The answer to this and the other problems must await further field investigations.

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¹Large species require good soil, and generally the poorer the soil, the smaller the species. This is well shown in the difference between extraordinarily large collembolan species and richer presentation of *Onychiuridae* in the fertile Mackenzie delta, and the few large species, almost no *Onychiuridae*, and many individuals of the small *Tullbergia* in the rocky terrain of Yellowknife (Hammer, 1953a, pp. 67-8).

REVIEWS

NORTH AMERICAN MOOSE

By RANDOLPH L. PETERSON. *Toronto: Univ. Press, 1955. 9 x 6 inches; xi + 280 pages and 25 unnumbered plates. \$12.50.*

Dr. Peterson can be congratulated on this useful book which is both well documented and well organized. The nineteen chapters and two appendices cover all major aspects of the biology of the moose, including taxonomy, paleontology, and postglacial dispersal of the species in North America. Most chapters are divided into sections, the titles of which are given in the table of contents. Some sections are further divided under italicized sub-titles, so that there are rarely more than two pages without a titled division. These headings, coupled with a good index, provide a means of quick and easy reference.

In the Introduction Dr. Peterson states that since 1946 he has devoted a major part of his time and effort to the study of the moose. This has evidently included considerable field work, mostly in Ontario. A few introductory paragraphs describing the areas covered by field work and the periods spent in them would have given the reader added interest and background. In the body of the book the author has rightly refrained from emphasizing his own work unduly, and, except for one chapter on the distribution and status of the moose in Ontario, he has drawn on the available information from all parts of North America, including northern Canada and Alaska. References are also made to European works.

Readers of *Arctic* who are not zoologists will be most interested in the short chapter on the postglacial dispersal of the moose in North America. It is there suggested that while range expansion in southern Canada probably resulted from habitat changes wrought by man, the northward spread of the species since

1875 may have been caused either by recent climatic amelioration or by a continuation of the pattern set by the retreat of the ice and tundra at the close of the glacial period. However, there must be some doubt whether the northward extension of the range towards and beyond the tree-line between Churchill and the mouth of the Mackenzie is a real advance or merely the result of the greater information now available. Also, the possibility of periodic expansion and contraction of the range needs more consideration. The possibly erroneous record of three moose seen by a seaman near Prince Albert Sound, Victoria Island, in mid-May 1851¹ is not mentioned. If the subspecies *Alces alces andersoni* and *A. a. americana* evolved during the glacial period respectively to the southwest and southeast of the great lakes, the far greater northward expansion of the former needs further explanation. Can the difference be due entirely to the late retreat of the ice from Ungava?

Since Dr. Peterson has dealt with the taxonomy of the genus *Alces* in an earlier paper,² only a synopsis is given in the present volume. The chapters on food habits and habitat studies are, with a few additions and changes, taken from his 'Studies of the food habits and the habitat of moose in Ontario',³ which deals more specifically and fully with Ontario. The two appendices, to which R. C. Passmore and A. T. Cringan have contributed, discuss methods of aging by mandibular tooth wear and antler development. Attention is drawn (Fig. 18) to

¹Armstrong, Alex. 1857. 'A personal narrative of the discovery of the North-West Passage'. p. 335.

²1952. 'A review of the living representatives of the genus *Alces*'. *Contrib. Roy. Ont. Mus. Zool. and Palaeontol.* No. 34, 30 pp.

³1953. *Contrib. Roy. Ont. Mus. Zool. and Palaeontol.* No. 36, 49 pp.

the reduced size of the pulp cavities in old animals, but the possible existence of annually deposited rings or ridges was apparently not checked. It is noted (p. 92) that the antler pedicle increases in diameter with age, and here again there is a possibility that stained sections might disclose annual rings.

The illustrations, binding, and format are suitable and adequate for a book of this kind, but it is by no means the luxury volume which the price would indicate. It is unfortunate that such a useful work, which should be in the hands of all moose hunters as well as zoologists working within the range of the moose in Canada, Alaska, the United States, and even Europe, has been published at a price which is double that of comparable volumes. It is strange that the publishers failed completely to realize the demand which adequate advertisement and a reasonable price might have created for this book.

T. H. MANNING

ATLAS DER EISVERHÄLTNISSE
DES NORDATLANTISCHEN
OZEANS UND ÜBERSICHTS-
KARTEN DER EISVERHÄLTNISSE
DES NORD- UND SUDPOLAR-
GEBIETES

DEUTSCHES HYDROGRAPHISCHES INSTITUT,
Hamburg: 1950. 19½ x 13½ inches; 18
pages text; bibliography; 34 charts.

The 1955 shipping season was particularly difficult in the Arctic, and reports of unusually poor weather and heavy ice were widespread. As surface traffic increases it is becoming obvious that our knowledge of average and extreme ice conditions must be improved, and that any studies that contribute to this knowledge are of great value. The German ice atlas, published in 1950, is not well known in North America. It is an enlarged edition of the publication produced during the last years of the Second World War by Dr. Julius Büdel of Deutsche Seewarte. Most of the first edition and the plates were destroyed in an air raid in 1944, but some charts were salvaged; they have been revised

by Deutsches Hydrographisches Institut and are used in this atlas.

The atlas is divided into two parts. The first part contains the text and a bibliography on sea ice with 37 titles, while the second part contains 34 charts. In spite of the date of publication no reference is made to 'Ice atlas of the northern hemisphere' published in 1946 by the Hydrographic Office, United States Navy, which contains an exhaustive bibliography on sea ice with no less than 1,700 titles.

Part I begins with a paragraph on sea ice in which the author states that the physical structure of winter ice in the seas distant from the north pole does not differ from that of the semi-permanent ice of the inner Polar Basin except in thickness "the one-year old winter ice seldom exceeds 1 metre, while the older polar ice on the average measures 2-3 metres in summer, and 3-4 metres in winter. Only in the case of exceptionally strong pressure and rafting can the ice occasionally reach a thickness of 25 metres. Normally the ice in the Polar Basin is 2-3 years old. Ice as old as 5-6 years is rare, and an age of 8 years is hardly ever exceeded". Nothing is said about the age of ice governing its salt content.

The author writes that the ice conditions of the inner Polar Basin and the neighbouring parts of the Canadian Archipelago are, even today, "almost unknown". He says that here there is "an ice cover that is uniform over vast distances, and of a permanent character; the lack of observations from this region is therefore not important for the geographical investigation of sea ice". This is a somewhat surprising statement. The manuscript for the text of the atlas was finished in 1947, and the maps, for the most part, show mean values for the period 1919-43; with a publishing date of 1950 one feels that the text, at least, might have been brought up to date. Although these areas can still be called "almost unknown" considerable study of the sea ice has been carried out in the North American Arctic since the Second World War. As the "lack of observa-

tions" has been remedied, surprising things have been found—for example, the ice conditions in Hudson Bay, and the number of ice islands floating in the Arctic Ocean, readily distinguished from the pack ice by their appearance.

The author considers that even more important than this lack of knowledge of ice conditions in the Polar Basin is the sporadic nature of our knowledge of the bordering zones. "These zones are subject to a constant periodic and non-periodic change between ice-free waters and an ice cover of many forms. Here, only two separate regions have been thoroughly investigated". The first includes Atlantic waters off Canada's coasts from the Gulf of St. Lawrence to Davis Strait, and, to a lesser extent, Baffin Bay, Hudson Strait and Hudson Bay, and the west coast of Greenland. The second includes the polar and sub-polar seas of the east and north Siberian coasts, and the western Barents Sea and the Spitsbergen waters, where the Norwegians have reported on ice conditions. However, it is stated, until recently very little was known of the ice conditions in the area between these regions where the largest periodic and non-periodic changes occur—the open North Atlantic extending from Spitsbergen to Denmark Strait and the southern tip of Greenland. From this area only single observations were available, and these mainly for the summer months. All these observations, as well as those from the Barents Sea and the west coast of Greenland, have been collected by the Danish Meteorological Institute since 1893, but "it is clear that the annual small-scale synoptic charts of ice distribution include only the summer months, and, the author continues, winter ice conditions have remained practically unknown. One would expect to find a reference to the work of Lauge Koch, published in 1945, which gives an exceptionally good description of the east Greenland ice, including the winter ice.¹ According to the text, the gap in knowledge of ice

conditions in this area was filled by the German Ice Reconnaissance Flights during the years 1941–45. A total of 250 flights was made between Denmark Strait and Spitsbergen-Franz Josef Land. The Ice Reconnaissance Flights carried out in the same regions by the Allied Air Forces are not mentioned. This work is described by Glen, who draws charts of monthly limits of drift ice and the probable means of limits of drift ice.¹

The atlas compares the ice regions of the various oceans, not only the yearly means of distribution, but also the occurrence of ice in percentages of frequency. The oceans are divided into three large regions: the North Atlantic Ocean with bordering seas, the whole north polar region, and the whole south polar region (the latter is defined as the southern oceans at any given time north to the equatorial limit of ice). Monthly charts have been drawn for each of these regions. However, there are only seven charts for the south polar region as, because of the dearth of observations during the winter half of the year, several months are represented by one chart.

A uniform method of presentation has been used for all these charts. It is a gradation of the mean frequencies of ice occurrence, "probability of ice", from 0 per cent probability (continuously ice free) to 100 per cent (continuous or almost continuous ice). Different symbols have been used to distinguish the two most important geographical types of ice, the polar sea ice and ocean ice, and the ice in the bordering seas of temperate latitudes. The charts of the North Atlantic are on a scale of 1:20,000,000; those of the north polar region are on a scale of 1:30,000,000 and for the south polar region the scale is 1:60,000,000.

For areas from which there are continuous observations the charts have been drawn for the same period. These include the North Sea and the Baltic Sea, the

¹Koch, Lauge. 1945. 'The east Greenland ice'. *Medd. om Grønl.* Vol. 130, No. 3, 373 pp.

¹Joubert, Sir Philip and A. R. Glen. 1946. "High latitude flying by Coastal Command in support of convoys to north Russia". *Geogr. J.* Vol. 108, pp. 1–21.

Danish and Russian observations in the Arctic Ocean and the North American observations in the Canadian-Greenland waters. In other areas "older sources" have been used, especially for the inner Polar Basin, the Canadian Archipelago, Hudson Bay, and the Gulf of St. Lawrence. These "older sources" give a surprisingly accurate picture of ice conditions in Hudson Bay, as they are now known to be.¹ In this the German ice atlas is better than the 'Ice atlas of the northern hemisphere' which shows Hudson Bay to be practically ice free, even in winter, beyond a narrow belt of land-fast ice.

The German ice atlas is intended for scientific as well as practical usage. For practical use it must be remembered that the outer limits of the symbols do not represent ice limits as in most charts of sea ice. The outer limits of symbols form a connecting link between points where ice was known to come farthest towards the open sea during the years

1919-43. All the local characteristics of an ice front cannot be indicated on a chart showing average ice conditions, and the lines for the different zones of probability follow a nearly straight, or only slightly curved, course for long distances. The introduction states that the atlas will "be a help to the navigator where no other assistance was available before": the risk in a voyage through all partially ice covered parts of the oceans can be read directly off the charts. The numerical values of probability are supplemented on each chart by additional notes on ice conditions. In spite of good printing and clear symbols, the charts will probably be less useful to the navigator in northern waters than the larger scale charts of the 'Ice atlas of the northern hemisphere' published four years earlier. However, a great deal of work has gone into the preparation of this new atlas, and it is a very welcome addition to our meagre knowledge of sea ice.

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INSTITUTE NEWS

Honorary degree conferred on Mr. W. A. Wood

At the 33rd Commencement Exercises of the University of Alaska on 16 May 1955 the honorary degree of Doctor of Science was conferred on Walter A. Wood, Director of the New York Office. Dr. Ernest N. Patty, President of the University of Alaska, presented Mr. Wood for his degree and spoke of his distinguished services in arctic exploration and geography. The degree was conferred by Elmer Rasmusson, Vice-President of the Board of Regents. In his commencement address Dr. Wood spoke of the changes that are taking

¹Hare, F. K. and Margaret R. Montgomery. 1949. "Ice, open water, and winter climate in the eastern Arctic of North America: Part II: The pattern of winter ice". *Arctic*, Vol. 2, pp. 149-64.

place in the north, and the opportunities and responsibilities that these changes present.

Other distinguished personages receiving honorary degrees included Sir Hubert Wilkins, for his exploratory and scientific work in the Arctic, and Dr. George W. Gasser, for his 48 years of pioneer service to Alaskan agriculture.

Award of Institute research grants

The following were awarded research grants, or otherwise sponsored, by the Institute for field work in the 1955 season:

BOYD, WILLIAM L. Dept. of Bacteriology, University of Georgia, U.S.A.

An ecological and taxonomic survey of microorganisms, under winter and summer conditions, in the vicinity of Point Barrow, Alaska.

CHAMBERLIN, J. LOCKWOOD. West Chester, Pennsylvania, U.S.A.

Winter investigations of the marine biology and hydrography of eastern coastal waters of James and Hudson bays.

DAY, ALBERT M. Washington, D.C., U.S.A.

A study of the programs and policies of all land and water use agencies which affect the breeding, protection, and perpetuation of migratory waterfowl in North America.

ELLIS, D. V. Dept. of Zoology, McGill University, Montreal, Quebec, Canada.

A continuation of studies of the distribution and ecology of the littoral and shallow water fauna and flora of the Canadian Arctic.

ELVEY, C. T. Geophysical Institute, College, Alaska.

Studies of absorption in the ionosphere, of earth currents, and of magnetic disturbances, auroral displays, and problems of radio propagation at Point Barrow, Alaska.

GORDON, MALCOLM S. Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, U.S.A.

Studies of the blood plasma and muscle in arctic char.

HAWN, BARBARA J. Dept. of Natural Resources, Oregon State College, Corvallis, Oregon, U.S.A.

A survey of the historical geography of tin on the Lost River, Seward Peninsula, Alaska.

HEUSSER, CALVIN J. American Geographical Society, New York, New York, U.S.A.

Pollen profiles from muskeg deposits in the Queen Charlotte Islands, British Columbia, and in the Olympic Mountains, Washington.

HOHN, E. O. Dept. of Physiology, University of Alberta, Edmonton, Alberta, Canada.

Ornithological field work with collecting and banding in the vicinity of Anderson River to Paulatuk, Mackenzie District, NWT.

HUBLEY, RICHARD C. Dept. of Meteorology and Climatology, University of Washington, Seattle, Washington, U.S.A.

Development and field testing of methods and instruments for accurate measurement of glacier budget, snow ablation, total-radiation balance, over a glacier surface.

MACGINITIE, MRS. GEORGE E. The Kerckhoff Marine Laboratory, California Institute of Technology, Corona Del Mar, California, U.S.A.

To make final checks, at the U.S. National Museum, Washington, D.C., for a paper on the molluscs of Point Barrow, Alaska.

MACVICAR, DONALD G., JR. Dept. of Geology, Yale University, New Haven, Connecticut, U.S.A.

Detailed field study and mapping of the Pleistocene and bedrock geology of the Chandler Lake area, Brooks Range, Alaska.

MONTGOMERY, B. ELWOOD. Dept. of Entomology, Purdue University, Lafayette, Indiana, U.S.A.

Ecology of the insects of the Arctic Slope of Alaska.

NARDONE, ROLAND M. Dept. of Biology, The Catholic University of America, Washington, D.C., U.S.A.

A study on the environment characteristics and tissue chemistry of the arctic black fish, in the vicinity of Point Barrow, Alaska.

NIELSEN, LAWRENCE E. Springfield, Massachusetts, U.S.A.

Preliminary glaciological and meteorological study of the Columbia Glacier region of the Chugach Mountains, Alaska.

PITELKA, FRANK A. Museum of Vertebrate Zoology, University of California, Berkeley, California, U.S.A.

A study of problems in lemming ecology based on recent work near Barrow.

RAY, G. CARLETON. Dept. of Zoology, Rutgers University, New Brunswick, New Jersey, U.S.A.

Continued environmental zoological investigations in the vicinity of Juneau, Alaska.

REED, EDWARD B. Dept. of Zoology, Colorado A & M College, Fort Collins, Colorado, U.S.A.

Investigation of the entomostracan

fauna in the lakes and ponds of the Colville and Canning rivers, Alaska.

REVELLE, ROGER. Scripps Institution of Oceanography, University of California, La Jolla, California, U.S.A.

A geologic study of the sea valley-submarine canyon system of Point Barrow, Alaska, and installation of tide gauges.

SCHOLANDER, PER F. Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, U.S.A.

Winter investigations of osmotic pressures in the blood of certain arctic and subarctic marine fishes in the vicinity of Hebron Fiord, Labrador.

SHANKS, ROYAL E. Dept. of Botany, University of Tennessee, Knoxville, Tennessee, U.S.A.

An investigation of the composition, structure, and productivity of the tundra vegetation of northern Alaska, in the vicinity of Point Barrow, Alaska.

TEDROW, JOHN C. F. New Jersey Agricultural Experiment Station, Rutgers University, New Brunswick, New Jersey, U.S.A.

A pedologic study of the soil-forming processes of the arctic coastal plain of Alaska.

USINGER, ROBERT L. Agricultural Experiment Station, University of California, Berkeley, California, U.S.A.

Reconnaissance study of amber deposits in the general vicinity of Point Barrow, Alaska.

WILCE, ROBERT W. Dept. of Botany, University of Michigan, Ann Arbor, Michigan, U.S.A.

Studies of the marine flora of Ungava Bay and northwest Labrador.

WILIMOVSKY, NORMAN J. Dept. of Zoology, Museum of Natural History, Stanford University, Stanford, California, U.S.A.

Continuation of the survey of the fishes of arctic Alaska, with particular reference to those of importance to the military and naval services.

Gifts to the library

The Institute library gratefully acknowledges gifts of books and reprints

from the following persons and organizations:

A. Bauer
H. Büttler
A. Cailleux
J. Corbel
A. Courtemanche
Marie S. Hammer
O. Heroux
R. C. Hubley
R. M. Jacklyn
W. W. Judd
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E. F. Roots
J. Sapin-Jaloustre
Marie A. Stafford
R. Tuomikoski
S. L. Tuxen
I. Whitaker
L. W. Wing

Alaska. Arctic Health Research Center, Library.

Alaska. University. Alaska Agricultural Experiment Station, Palmer.

Australia. Department of External Affairs. Antarctic Division.

British 'Greenland Expedition.

Canada. National Research Council.

Canada. National Research Council. Associate Committee on Soil and Snow Mechanics.

Cornell University. College of Engineering.

Eidgenössische Technische Hochschule, Zürich.

Institute of Low Temperature Science, Hokkaido.

Mechanics Institute of Montreal.

Library.

Michigan University. Museum of Paleontology.

NORTHERN NEWS

Eastern Arctic fisheries investigations, 1947-55

During the summer of 1947, as part of a program for the development of arctic marine resources, the Fisheries Research Board of Canada began preliminary investigations in Ungava Bay. Serious nutritional deficiencies had been reported amongst the native inhabitants of the area, and it was hoped that some marine resources would be discovered that they could use themselves to raise their standard of living. The first season's work indicated that a cod fishery might be possible at Port Burwell, in the northeast of Ungava Bay, but it was clear that further investigations were necessary and that they would require the services of a properly equipped research vessel. Accordingly, in 1948, the *Calanus*, a diesel-powered ketch, was designed and built for the Fisheries Research Board of Canada at Mahone Bay, Nova Scotia;¹ she was launched in August, and made her maiden voyage to Fort Chimo, Ungava Bay, which was to be her base for the next few years.

In the summer months of 1949 and 1950 the *Calanus* collected data fundamental to the study of the physical and biological oceanography of Ungava Bay. The results of this research show several good possibilities for exploitation of the natural resources. The Atlantic cod (*Gadus callarias*) is sufficiently plentiful at Port Burwell to form the basis of a good local, native fishery, whilst the Greenland shark (*Somniosus microcephalus*), though only seen in small numbers, might be hunted profitably in the fall. The development of these resources would involve the provision of financial assistance to the fishery and suitable education of the native population.²

¹Dunbar, M. J. 1949. "*Calanus*, new arctic research vessel". *Arctic*, Vol. 2, pp. 56-7.

²Dunbar, M. J. 1952. "The Ungava Bay problem". *Arctic*, Vol. 5, pp. 4-16.

In 1951 the *Calanus* began research in east Hudson Strait, and the waters of southeast Baffin Island. Trawling and long-line fishing in Frobisher Bay yielded poor results; no sharks were encountered. Studies were carried out on the arctic char (*Salvelinus alpinus*), which was abundant at the head of the bay and in the Sylvia Grinnell River.

Investigations were continued in Frobisher Bay during the summer of 1952, and a study of Cumberland Sound was begun. Unfortunately serious engine trouble reduced the efficiency of the *Calanus* and the program of biological and hydrographical work was not completed. So that she might make an early start in the following summer, the ship was wintered that year at Churchill.

The study of seals and walrus formed the main part of the field work in the 1953 season, and the fine weather also allowed a full program of hydrographic work to be done in western Hudson Strait and northern Hudson Bay. Seals were especially numerous along the south side of Foxe Peninsula. Walrus were found in moderate numbers around northern Coats Island, and at Seahorse Point, Southampton Island; the estimated total for the northern Hudson Bay herd was between two and three thousand adults and young.

In July and August 1954 work was continued on the walrus census and general marine biology associated with the walrus study; this included quantitative and qualitative plankton hauling, bottom sampling, hydrographic work and experiments on the measurement of productivity in the waters between Coral Harbour, Southampton Island, and Coats Island. As the migration of walrus presents a fundamental research problem, tagging experiments were carried out at Coats Island during late July and early August. Simultaneously, another tagging program was being carried out by the

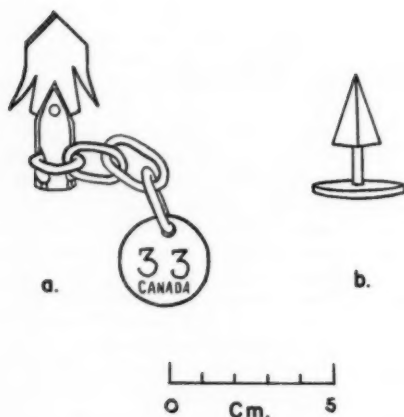


Fig. 1. Tags used in walrus survey.

Canadian Wildlife Service at Bencas Island (northeast of Coats Island) and in the vicinity Seahorse Point.

The first tag used by the Wildlife Service was a stainless steel copy of the Eskimo seal harpoon head. This was modified in the field as the chain prevented the head from penetrating deeply enough into the skin for it to turn and hold fast. The new tag was smaller, and did not rotate but merely penetrated the skin layer, sticking in the epidermis when the harpoon shaft was withdrawn (Fig. 1a). Thirty animals were marked, and three recoveries were made in the fall. One tag had been rubbed off and was found on Coats Island; the other two were taken by natives during the fall hunt. Eskimo opinion was that tagged walrus might become "sick", and it was felt that a smaller and less harmful tag would be better.

The *Calanus* tag is shown in Fig. 1b, and only simple modifications were necessary in the light of field experience. The original conical head was ground to pyramidal shape to provide four cutting edges for easier penetration of the epidermis. The Eskimo consider that this tag should work well and be unharmed to the walrus. Twenty-three animals were tagged, but no recoveries have been made as yet. Tags were kept sterile in absolute alcohol before use, but it has been suggested that in future the use of

an anti-biotic cream would reduce the possibility of infection.

Detailed work on the ringed seal (*Phoca hispida*) was carried out at Cape Dorset, Baffin Island, from February until October 1954 by one member of the staff. He travelled extensively with Eskimo hunters, and a large collection of specimens was obtained. The field work shows that the most important factor determining the distribution of the ringed seal in the arctic zone is the length of the period of ice cover; this, in turn, is directly related to the complexity of the coastline.

At the end of the 1954 season the *Calanus* left Coral Harbour and sailed to Montreal for the first refit since her launching in 1948. The old winches were replaced by new hydraulically operated units, the main deck winch being capable of handling up to two tons, and a gyro-compass and a new radio telephone were installed. The general inspection and overhaul were completed in June 1955, and the *Calanus* was able to leave Montreal for another season of work in the north on June 29.

The journey to Southampton Island was greatly delayed by strong winds and much drift ice, particularly at Nain on the Labrador coast. The *Calanus* eventually reached Coral Harbour on August 15, which left little time for the proposed biological work along the east

coast of Hudson Bay and south to the Belcher Islands. It was, therefore, decided that she should stay at Coats Island and continue the previous year's program of walrus work. Thirty-seven adult animals and two young were marked with the stainless steel tags, and a collection of specimens made. These supplemented the specimens taken by the writer earlier in the year at the floe-edge south of Coral Harbour, and later in the fall at Coats Island.

On September 4 the *Calanus* left for Igloodik by way of Roes Welcome Sound, reaching the north of Foxe Basin with little difficulty. However, in the vicinity of Jens Munk Island she had to wait for ten days before she could navigate through the pack ice and take up her winter quarters in the harbour at Igloodik. During the coming winter the captain and chief scientist will remain on board. They will make regular plankton hauls and hydrographic observations from fixed points on the sea ice, and will collect further data on walrus biology.

The results of all this work can be found in the following publications as a "Calanus" Series in the *Journal of the Fisheries Research Board of Canada*:

Bousfield, E. L. 1955. "The cirripede Crustacea of the Hudson Strait region, Canadian Eastern Arctic". Vol. 12, No. 5, pp. 762-7.

Dunbar, M. J. 1954. "The amphipod Crustacea of Ungava Bay, Canadian Eastern Arctic". Vol. 11, No. 6, pp. 709-98.

Dunbar, M. J. and E. H. Grainger. 1952. "Station list of the 'Calanus' expeditions, 1947-50". Vol. 9, No. 2, pp. 65-82.

Dunbar, M. J. and H. H. Hildebrand. 1952. "Contribution to the study of the fishes of Ungava Bay". Vol. 9, No. 2, pp. 83-128.

Fontaine, M. 1955. "The planktonic copepods of Ungava Bay". (In press).

Grainger, E. H. 1953. "On the age, growth, migration, reproductive potential, and feeding habits of the Arctic char (*Salvelinus alpinus*) of Frobisher Bay, Baffin Island". Vol. 10, No. 6, pp. 326-70.

1954. "Station list of the *Calanus* expeditions 1951-52, together with Frobisher Bay Stations, 1948, 1950 and 1951, and Resolution Island Stations, 1950". Vol. 11, No. 1, pp. 98-105.

1954. "Polychaetous annelids of Ungava Bay, Hudson Strait, Frobisher Bay and Cumberland Sound". Vol. 11, No. 5, pp. 507-28.

1955. "Echinoderms of Ungava Bay, Hudson Strait, Frobisher Bay and Cumberland Sound". (In press).

1955. "Station lists of the *Calanus* expeditions, 1954-55". (In press).

A. W. MANSFIELD

The Beaver Index

The Hudson's Bay Company first published *The Beaver, Magazine of the North* in 1920 as a journal "Devoted to the interests of those who serve the Hudson's Bay Company", but since that time it has become one of the most widely read magazines on the north. Imaginative editing, particularly by Clifford Wilson the present editor, has produced a magazine full of interesting and informative articles on travel, exploration, pioneer activities, and trade in the Canadian north, many of them beautifully illustrated. This wealth of information has been made more readily accessible by the publication, early this year, of the Index covering issues from October 1920 to March 1954. The entries are arranged alphabetically under author, title, and subject, and the excellent illustrations are also indicated. The Index is 63 pages long, and is the same size as the magazine. It is to be hoped that in the future the Index to *The Beaver* will be published more frequently.

Scientific work at the Danish Arctic Station, summer 1954

In summer 1954, during his first year as scientific leader of the Danish Arctic Station at Godhavn, west Greenland, Ulrick Røen began two parallel studies. First, he studied the biology and ecology of arctic entomostracan fauna. About fifty large and small freshwater areas, and some brackish water areas near Godhavn, in Disko Fjord, around Jakobs-havn, and at the head of Disko Bugt were investigated as regularly as weather and transport conditions permitted. Measurements were made of water temperature, conductivity, pH factor, colour, oxygen content, and NaCl, Fe⁺⁺, and

Fe+++ content. It is hoped that further factors may soon be measured with the newly installed electrical equipment. In addition to these chemical and physical measurements, quantitative and qualitative collections were made of Entomostraca, and representative collections were made of Rotifera, Hydrachnidae, Diptera, Tardigrada, and Nematoda.

Second, Røen studied the ecology of arctic lakes. Limnological-hydrographical investigations combined with quantitative and qualitative bottom samples and plankton samples were made in two large lakes, "Mellemø" in Disko Fjord, and Tasersuaq at Atâ on the west side of Arveprinsens Ejland. During the summer a complete survey was made of "Mellemø", and a series of temperature and oxygen measurements taken.

Several scientists visited the station to carry out field work. Dr. Finn Salomonsen and Mr. Sigurd Bruun travelled through the fiord system between Egedesminde and Holsteinsborg in the station's motor boat, *Holck*, to ring breeding birds: Dr. Axel M. Hemmingsen studied Tipulidae in the immediate neighbourhood of the Arctic Station, and also near Disko Fjord.

Seminar on arctic meteorology, McGill University

The McGill Geography Summer School was held at Stanstead College, Stanstead, Que., from 26 June to 6 August 1955. This year the special arctic program included a ten-day seminar on arctic meteorology, under the chairmanship of Professor F. K. Hare, which was organized by the McGill Arctic Meteorology Research Group, and was sup-

ported in part by the Geophysics Research Directorate, U.S. Air Force Cambridge Research Center. Thirty meteorologists took part, including representatives from the U.S. services, the Canadian Department of Transport, and several universities. All those attending were either active in northern meteorological research or were forecasters with arctic experience.

The seminar covered most aspects of polar meteorology and special stress was laid on the International Geophysical Year program for polar regions. Dr. Svenn Orvig, Director of the Arctic Institute's Montreal Office, helped organize the program and spoke on glacial meteorological research. Dr. Warren Godson, Superintendent, Atmospheric Research, Meteorological Division, Department of Transport, presented four papers. Guest speakers included Dr. Richard Reed, Department of Meteorology, University of Washington, and Dr. Millett Morgan, Dartmouth College, Chairman of the U.S. Ionospheric Panel for the forthcoming International Geophysical Year, and many other participants also presented informal papers. At the final session, suggestions were gathered for future research. These suggestions, and a selection of the informal papers presented will be published by the McGill Arctic Meteorology Research Group.

Errata, Vol. 8, No. 1

Page 53, Fig. 4. The caption should read *Sea otter eating while swimming on back in holding tank.*

Page 75, caption. For *Kista Dan* read *Magga Dan.*

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